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CHARLES F. MARVIN, Chief

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (*b*) abstracts or reviews of important meteorological papers and books, and (*c*) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology ,and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but **the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW or SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

As the surplus of MONTHLY WEATHER REVIEW, February, April, June, July, and August, 1919, is exhausted, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage. The return of other issues of 1919 and earlier years will also be appreciated.

CORRIGENDA.

REVIEW, December, 1919:

P. 863, 2d column, 9th line from bottom, *for* "March, 1897" *read* "March, 1907".
P. 869, 1st column, end of third paragraph, the expression "$e-.0001036y$" *should read* "$e^{-.0001036y}$".

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

Vol. 48, No. 1. W. B. No. 704. | JANUARY, 1920. | Closed Mar. 5, 1920 Issued Apr. 2, 1920

REDUCTION OF THE REVIEW.

This volume of the Monthly Weather Review opens on a reduced basis, averaging 60–65 numbered pages (instead of 75–80), 1–3 plates, and the regular number of lithographed charts. The curtailment, which began with the November issue, has been rendered necessary because of a number of factors: (1) Twenty per cent increase in the cost of publication; (2) increased amount of aerological data to be published; (3) large size of the Monthly Weather Review in 1919, and (4) additional expense for larger edition and larger number of separates to meet the increased demand. The average space allotment per issue is planned as follows: Contributions (including illustrations in text), 23 pages; abstracts, reviews, notes, reprints, and bibliography, 20 pages; solar data, 1 page; weather of the month, 14 pages; and seismology, 4 pages. Since the cut falls almost exclusively on the space available for contributions, yet still leaves a good opportunity for publishing them, it is hoped that there will be but little loss in the usefulness of the Review in spite of the reduced number of pages.—Editor.

AVERAGE FREE-AIR CONDITIONS AS OBSERVED BY MEANS OF KITES AT DREXEL AEROLOGICAL STATION, NEBR., DURING THE PERIOD NOVEMBER, 1915, TO DECEMBER, 1918, INCLUSIVE.

By Willis Ray Gregg, Meteorologist.

[Weather Bureau, Washington, Feb. 27, 1920.]

SYNOPSIS.

During the period, November, 1915, to December, 1918, 1,579 free-air observations[1] were obtained by means of kites at Drexel, Nebr. These include a large number that were made as parts of series of successive flights whose purpose was the determination of the diurnal variation of different elements at various altitudes. In the present summary the extra observations have not been used; only one for each day, usually the highest during the daytime. In this way equal weight is given to each day in the computation of monthly, seasonal, and annual means. In all, 1,074 days are represented, failures on the remaining 83 days being due for the most part to light winds. In the consideration of free-air winds in relation to those at the surface all observations obtained in the daytime have been included.

A discussion of the reliability of the data indicates that instrumental and observational errors have been largely eliminated; that the monthly distribution is good; that the diurnal distribution is less satisfactory, but probably fairly representative, at any rate for all levels a short distance above the surface; but that, owing to the shortness of the period under consideration and its wide departures at times from normal conditions, some of the monthly means can not be considered as normal values. These irregularities largely disappear, however, in the seasonal and annual averages; and the latter, especially, may be accepted as closely approximating true conditions. In considering free-air winds it is necessary to bear in mind that the averages given do not include days with very light or very strong winds, since kites can not be flown under those conditions.

Tables and figures give mean monthly, seasonal, and annual values of the different elements at various levels up to 5 kilometers. The data are compared with similar data for Mount Weather, Blue Hill, and elsewhere, and a separate table contains comparative values of air density, as determined by different investigators for various parts of the world

INTRODUCTION.

The purpose of this summary is to present in brief and convenient form for the information and use of artillery and aviation services the results of free-air observations[1] that have been secured by means of kites at Drexel, Nebr. No attempt is made for the present to discuss these results further than to indicate their reliability as normal values and to give some comparative data for other places.

Number and distribution of observations.—During the period under consideration, viz, November, 1915, to December, 1918, inclusive, kite flights were made on 1,074 days. Failures on the remaining 83 days were due in most cases to lack of wind and were distributed quite evenly among the different months. In all, 1,579 observations were obtained; on some days a second flight was made when it was thought that a greater altitude could be reached than in the first one; but in most cases the extra observations were obtained in the course of diurnal series consisting of 8 flights on the average and covering periods of 24 to 36 hours. In the computation of mean monthly, seasonal and annual values presented in tables 4, 6, and 7 these extra observations have not been used, it being thought that undue weight might thus be given to certain days that were particularly favorable for kite flying. When more than one flight was made on a single day the highest as a rule has been used, except that, in the case of diurnal series, none of those made at night has been considered. The number of observations, monthly, seasonal and annual and at various altitudes, upon which are based the values given in Tables 4, 6, and 7 may be found in Table 1. The monthly distribution at all altitudes is fairly good, the larger number in November and December being due to the fact that those two months are represented by four years' observations, whereas the other months are represented by only three. More than half of the flights extend to an altitude of 3 kilometers above sea level, but the number

[1] By "observation" is meant a complete record of free-air conditions at various altitudes, as obtained in each kite flight. As a rule, such a record makes possible the computation of values at several different altitudes. These separate determinations might themselves be called observations, but are not so considered here.

rapidly diminishes at higher levels. The average height reached in all flights is about 2,900 meters above sea level, or 2,500 above the surface.

In the study of free-air winds in their relation to surface wind direction it has been thought best to consider *all* observations that were made in the daytime. Thus, if there were two or more observations on a single day, each one was given equal weight, since in this case it is not a monthly or seasonal mean that is desired but rather the connection between conditions at the surface and in the free air. In some instances, moreover, winds were observed when other elements were not recorded because of instrumental defects. For these reasons the total number of observations on which are based the values given in Tables 8 to 11 is somewhat larger than the total number in Table 1. The distribution according to surface direction may be seen in Table 2. The figures at various levels above the surface represent the number of observations made when the surface direction was that indicated in column 1. They do not mean that that direction was itself observed at those levels. The last column in the table shows the percentage frequency of surface winds from the 16 directions given in column 1.

Reliability of the data.—All records were obtained with meteorographs of the type designed by Prof. C. F. Marvin. Instrumental and other errors have been reduced to a minimum by frequent calibrations, by detailed notes of surface conditions during flights and by the method employed in reducing the data, i. e., dividing the work among several computers. Although there may be, and probably are, appreciable errors in the case of some of the individual records, it is believed that these are largely, if not altogether, eliminated in the means of a large number such as we are now considering. The original data have been published in detail in MONTHLY WEATHER REVIEW SUPPLEMENTS Nos. 3, 5, 7, 8, 10, 11, 12, 13, 14, and 15 (Aerology Nos. 1 to 10, inclusive). In these SUPPLEMENTS have also been given mean monthly temperatures. These and other mean values that appear in the present paper have been determined by applying to the average surface conditions the mean gradients from each level to the next higher level. In this way artificial discontinuities, due to the dropping out of observations in the higher levels, have been avoided, and the results represent more nearly true averages than would the means of the actually observed values themselves.

As previously stated, the monthly distribution of observations is very good. The diurnal distribution is less satisfactory. The diurnal variation of temperature at the surface is more pronounced than is that of any other meteorological element. It may therefore very properly be taken as the basis of classifying the observations, so far as time is concerned. If we do this we find that these observations naturally divide themselves into two groups: the first comprising all of those made up to the time of maximum temperature, 3 p. m.; and the second, those made after this time. There are 82 per cent in the first group and 18 in the second, the average times being 10:45 a. m. and 5:28 p. m., respectively, and the corresponding surface temperatures, 10.5° C. and 12.8° C. If these be weighted in proportion to the number of observations which each represents, the result is found to be 10.9° C., or 1.1° C. higher than that shown under "Annual" values in Table 4. The latter, i. e., the mean surface value observed during kite flights, represents quite closely the conditions at 10 a. m. and 8 p. m., and it is probable that the values at higher levels are similarly representative of conditions at those hours of the day. When we consider 24-hour means, we find that a small minus correction is necessary. To what height this extends is uncertain, but it probably decreases rapidly and disappears within the lower 1,500 meters. A preliminary study of a large number of records obtained during successive flights extending over periods of 24 to 36 hours indicates that the diurnal change in temperature vanishes at about 1,000 to 1,500 meters; at greater heights there seems to be no consistent variation; at Mount Weather (**1**) and Blue Hill (**2**) a small reversal in type was found in the higher strata.

The reliability of the data depends not only upon the monthly and diurnal distribution, but also upon the character of the period during which the data were obtained, i. e., the closeness with which that period represents normal conditions. In order to determine this the departures from normal as given in the climatological summaries published in the MONTHLY WEATHER REVIEW for the Missouri Valley Climatological District have been used, Drexel having been in operation for too short a time to make it possible to compute normal values for that station. The results for pressure and temperature, as well as other miscellaneous data more or less related to those given in Tables 4, 6, and 7 are presented in Table 3. For convenience in comparing them with 24-hour means and with normal values, the surface values observed during kite flights are also given in this table. Briefly, the figures show that there is, on the whole, very good agreement between the values observed during kite flights and the 24-hour means. Pressures and temperatures are slightly higher, since the flights are made near the times of diurnal maximum of these elements; relative humidities are lower; hence, vapor pressures are nearly the same; and wind velocities are higher, partly because the maximum occurs during the daytime, partly because flights can not be made during very light winds. Perhaps the latter reason also applies in the case of wind directions, in which the differences are large, especially during spring and summer, when easterly winds of too low a velocity for kite flights are frequent.

When compared with *normal* values the data show very conclusively that the period under consideration is too short for the determination of absolutely reliable means, at any rate so far as monthly means are concerned. Even five years are insufficient. [See Table 3, reference (**3**).] Probably a 10-year period is necessary. In Table 3 variations from the normal pressure are most pronounced in February, April, August, September, and October; and from normal temperature and density in March, July, and November. These discrepancies largely disappear in the seasonal and especially in the annual values, and the latter can indeed be accepted as representing very nearly normal conditions. For example, the variation in density is less than one-half of 1 per cent in the seasonal and annual means.

FREE-AIR DATA.

In Table 4 may be found mean values of barometric and vapor pressures in millimeters and millibars; temperatures and temperature gradients in °C.; relative humidities in percentages; and densities in percentages of standard density (1.293 kg. per m.³) and in kilograms per cubic meter. The values are given for various heights up to 5 kilometers and for the months, seasons, and year. Those at sea level have been estimated by extrapolation. Wind data are given separately in Tables 6 to 11.

Pressures.—The annual variation of pressure at the surface, as shown in the table and in figure 1, is small. At about 250 meters above the surface a reversal occurs and

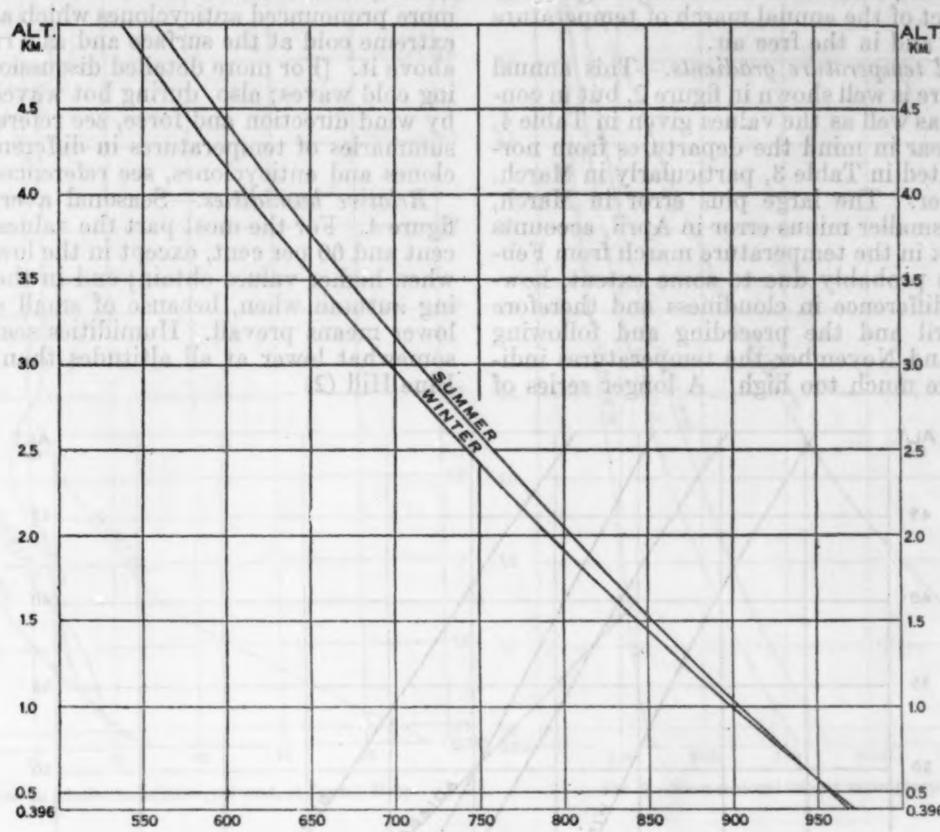

FIG. 1.—Mean summer and winter free-air pressures, mb., at Drexel, Nebr.

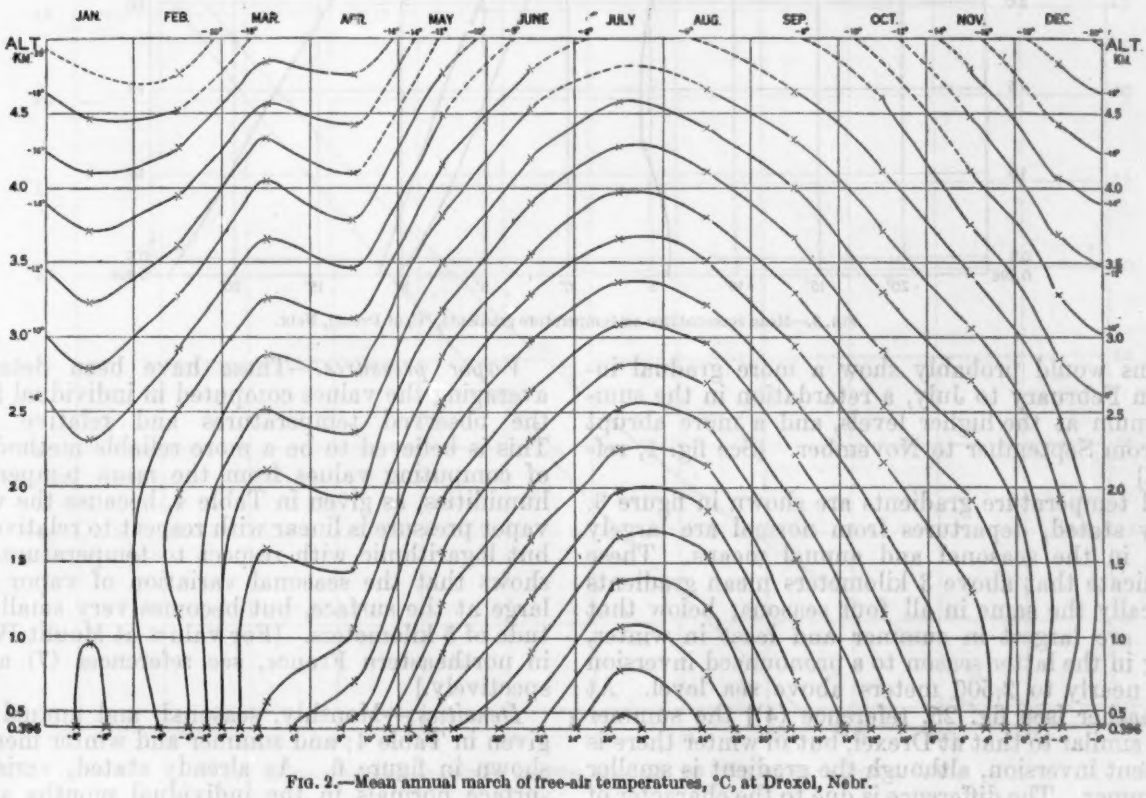

FIG. 2.—Mean annual march of free-air temperatures, °C, at Drexel, Nebr.

at higher levels the difference between summer and winter pressures gradually increases with increasing height, due of course to the effect of the annual march of temperature both at the surface and in the free air.

Temperatures and temperature gradients.—This annual march of temperature is well shown in figure 2, but in considering this figure, as well as the values given in Table 4, it is necessary to bear in mind the departures from normal that are presented in Table 3, particularly in March, July, and November. The large plus error in March, combined with the smaller minus error in April, accounts in part for the break in the temperature march from February to May; it is probably due to some extent, however, to the large difference in cloudiness and therefore in sunshine in April and the preceding and following months. In July and November the temperatures indicated in figure 2 are much too high. A longer series of observations would probably show a more gradual increase from February to July, a retardation in the summer maximum at the higher levels, and a more abrupt decrease from September to November. [See fig. 1, reference (3).]

Seasonal temperature gradients are shown in figure 3. As already stated, departures from normal are largely eliminated in the seasonal and annual means. These curves indicate that above 3 kilometers mean gradients are practically the same in all four seasons; below that level they are largest in summer and least in winter, amounting in the latter season to a pronounced inversion extending nearly to 2,500 meters above sea level. At Mount Weather [see fig. 25, reference (4)] the summer gradient is similar to that at Drexel, but in winter there is no permanent inversion, although the gradient is smaller than in summer. The difference is due to the character of the climates at the two places, that at Mount Weather being semimarine and that at Drexel distinctly continental; moreover, the latter station lies in the path of the more pronounced anticyclones which are characterized by extreme cold at the surface and as a rule by an inversion above it. [For more detailed discussion of gradients during cold waves; also, during hot waves and as influenced by wind direction and force, see reference (5). For brief summaries of temperatures in different quadrants of cyclones and anticyclones, see references (3) and (6).]

Relative humidities.—Seasonal averages are shown in figure 4. For the most part the values lie between 50 per cent and 60 per cent, except in the lower levels in winter, when higher values obtain; and in the higher levels during autumn when, because of small average cloudiness, lower means prevail. Humidities seem to be in general somewhat lower at all altitudes than those observed at Blue Hill (2)

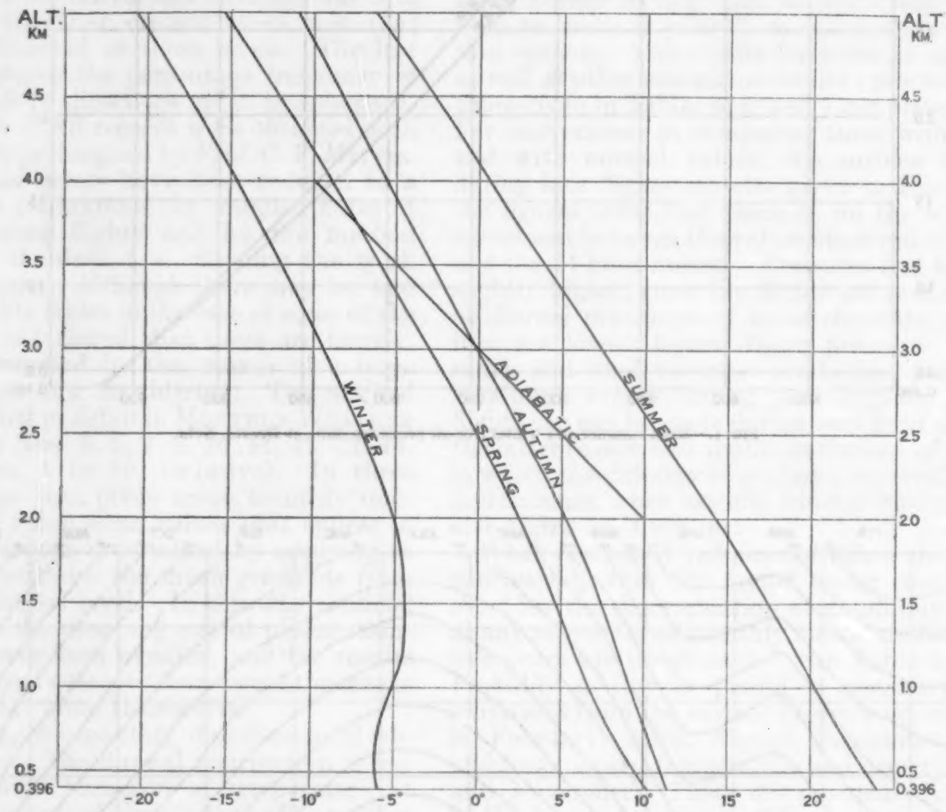

FIG. 3.—Mean seasonal free-air temperature gradients, °C, at Drexel, Nebr.

Vapor pressures.—These have been determined by averaging the values computed in individual flights from the observed temperatures and relative humidities. This is believed to be a more reliable method than that of computing values from the *mean* temperatures and humidities, as given in Table 4, because the variation of vapor pressure is linear with respect to relative humidity, but logarithmic with respect to temperature. Figure 5 shows that the seasonal variation of vapor pressure is large at the surface, but becomes very small at an altitude of 5 kilometers. [For values at Mount Weather and in northeastern France, see references (7) and (8), respectively.]

Densities.—Monthly, seasonal, and annual means are given in Table 4; and summer and winter means are also shown in figure 6. As already stated, variations from surface normals in the individual months are in some cases considerable, the largest amounting to about 1.5

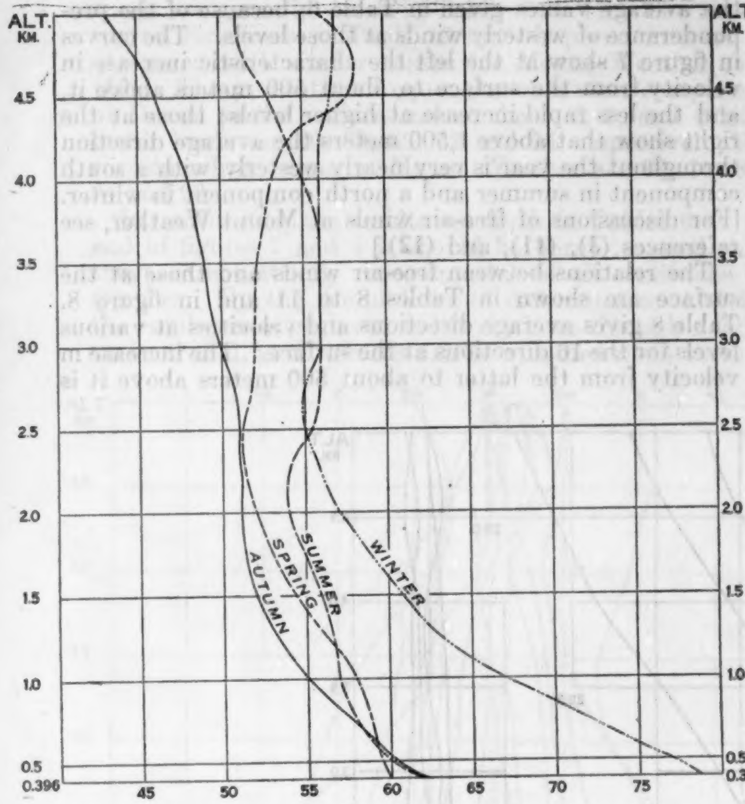

FIG. 4.—Mean seasonal free-air relative humidities, per cent, at Drexel, Nebr.

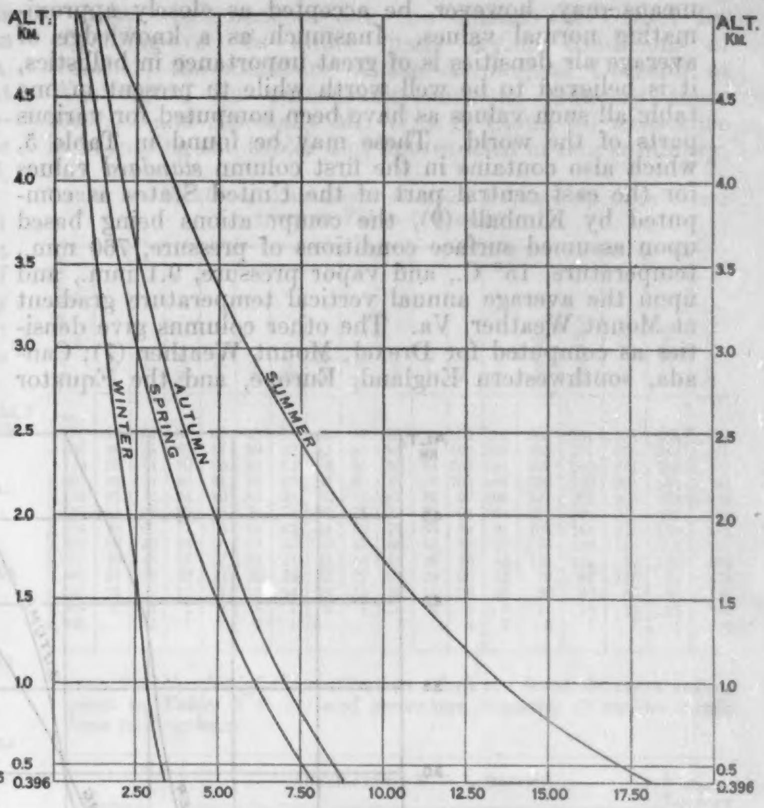

FIG. 5.—Mean seasonal free-air vapor pressures, mb., at Drexel, Nebr.

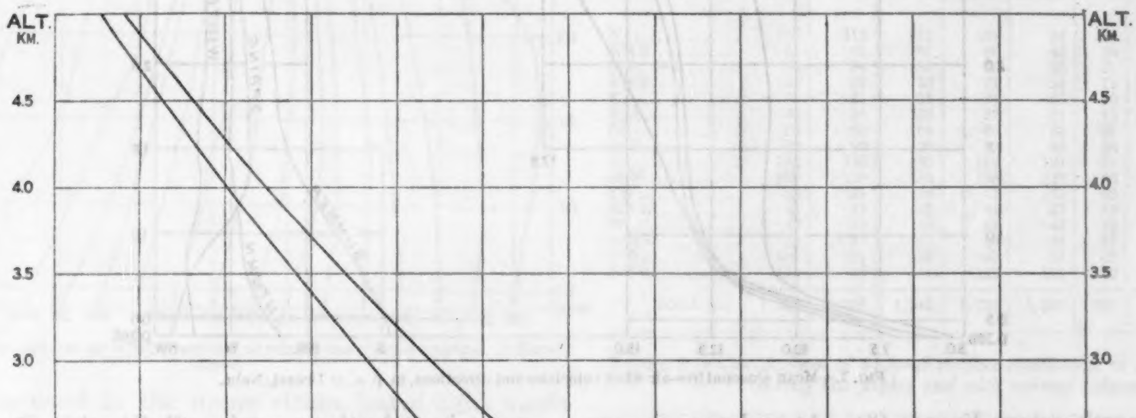

FIG. 6.—Mean summer and winter densities, kilograms per cubic meter, at Drexel, Nebr.

per cent in March. (See Table 3.) Seasonal and annual means may, however, be accepted as closely approximating normal values. Inasmuch as a knowledge of average air densities is of great importance in ballistics, it is believed to be well worth while to present in one table all such values as have been computed for various parts of the world. These may be found in Table 5, which also contains in the first column *standard* values for the east central part of the United States as computed by Kimball (**9**), the computations being based upon assumed surface conditions of pressure, 760 mm., temperature, 15° C., and vapor pressure, 9.1 mm., and upon the average annual vertical temperature gradient at Mount Weather, Va. The other columns give densities as computed for Drexel; Mount Weather (**7**); Canada, southwestern England, Europe, and the Equator (**10**); and northeastern France (**8**). At and near the surface latitudinal differences corresponding to latitudinal temperature changes are in evidence; these have largely disappeared at an altitude of 5 kilometers, except in the equatorial regions; at 9 kilometers there is practically no variation in any of the regions represented.

Wind directions and velocities.—The aviator is most interested in the *average* winds of a place or season; the meteorologist, in the *resultant* winds. These are given for the seasons and the year in Tables 6 and 7, respectively. Mean values for the seasons are also shown in figure 7. They are actual means, the directions and velocities having been considered independently. The resultants, on the other hand, have been determined by first resolving each observation into its north and west components and then computing the resultant values. At and near the surface, as indicated in Table 7, the resultant velocities are low because in the lower levels winds blow with about equal frequency from all four quadrants; at higher levels they more nearly approach the average values given in Table 6, because of the preponderance of westerly winds at those levels. The curves in figure 7 show at the left the characteristic increase in velocity from the surface to about 500 meters above it, and the less rapid increase at higher levels; those at the right show that above 1,500 meters the average direction throughout the year is very nearly westerly, with a south component in summer and a north component in winter. [For discussions of free-air winds at Mount Weather, see references (**3**), (**11**), and (**12**).]

The relations between free-air winds and those at the surface are shown in Tables 8 to 11 and in figure 8. Table 8 gives average directions and velocities at various levels for the 16 directions at the surface. The increase in velocity from the latter to about 500 meters above it is approximately the same for all directions, but at greater altitudes easterly winds generally decrease slightly, at the same time changing to westerly, whereas surface westerly winds continue to increase as higher levels are reached. The turning with altitude is well brought out in figure 8. In general surface easterly to southwesterly winds veer with altitude; west-southwesterly to west-northwesterly winds remain practically constant; northwesterly to north-northeasterly winds back slightly; and northeasterly and east-northeasterly winds change but little up to 2 kilometers, above which level they back and veer, respectively. The figure shows further that the veering or backing of these winds is such that a west component prevails at 3,000 meters for all surface winds; that the convergence continues until at 4,000 meters winds are nearly always between northwest and southwest; and that the north or south component in the surface winds still persists at the highest levels explored. These relations between surface and free-air

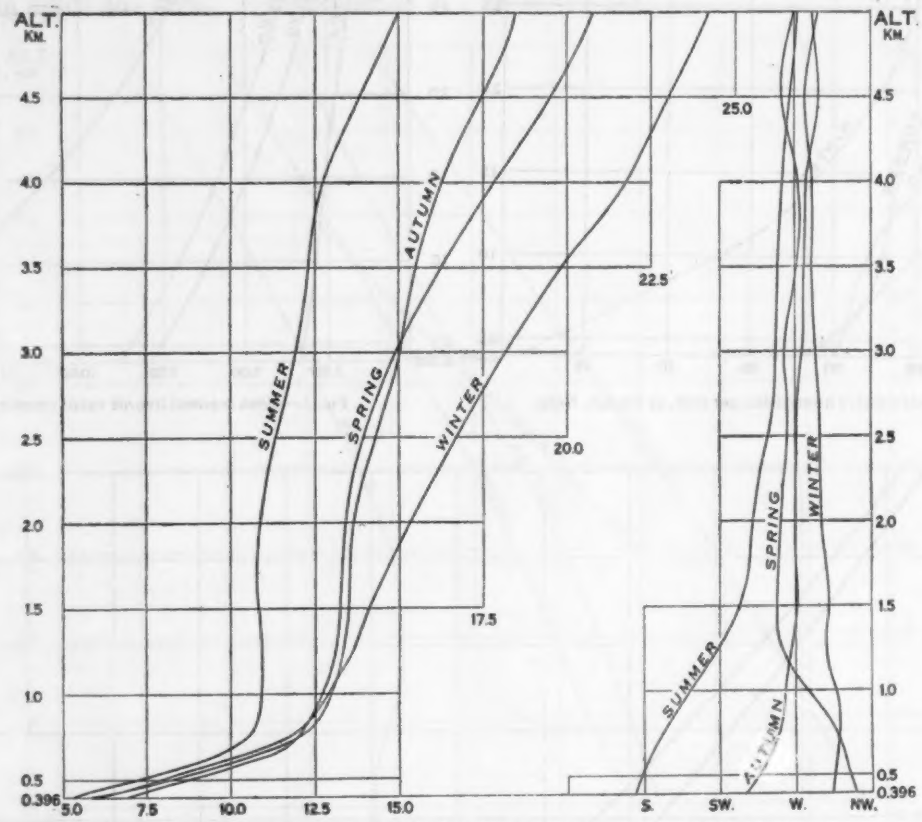

FIG. 7.—Mean seasonal free-air wind velocities and directions, m. p. s., at Drexel, Nebr.

winds are given in detail in Tables 9 to 11. The means for all directions in Table 10 are of special interest as compared with similar means for Mount Weather, Va. (**12**). The percentage frequencies of a west component at Drexel at the surface and at the 1, 2, 3, and 4 kilometer levels are 60, 68, 83, 92 and 95, respectively; the corresponding values at Mount Weather are 66, 79, 88, 94 and 96.

In considering the results set forth in Tables 6 to 11 and in figures 7 and 8 it should be borne in mind that they are not strictly representative of all conditions of weather. By the use of kites of different sizes and by the employment of power to lift the kites through a light surface wind, good records can be obtained when there is

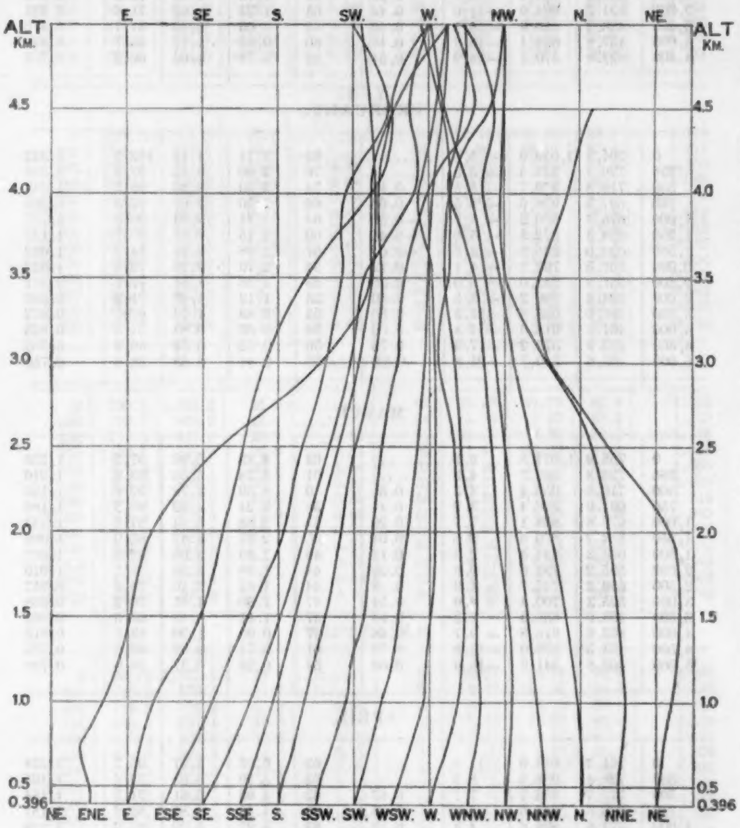

FIG. 8. Mean annual free-air wind directions, as related to surface directions, at Drexel Nebr.

a moderate wind in the upper strata, but if light winds prevail at all altitudes or, on the other hand, if there are excessively strong winds, such records can not be obtained. The former condition is more frequent in summer, and the latter in winter. Presumably, therefore, actual summer averages are lower, and winter averages are higher than those given; the annual means are probably very nearly correct. Again, since light winds are usually those from an easterly direction, the mean values in Table 10 are perhaps slightly higher than they should be. There are now available for study a large number of pilot-balloon records obtained in different parts of the United States. These will soon be summarized and will in all probability throw much additional light on the behavior of winds in the free air. Balloons, however, have their limitations also, since they can not be observed in cloudy weather nor to great heights when winds are strong. The inventive genius who will devise a method for obtaining continuous records at various altitudes will make for himself a secure place in the esteem of all meteorologists.

Acknowledgment is due the officials at Drexel for obtaining records under many trying conditions of weather; the members of the Aerological Division at Washington for painstaking care in reducing those records; and especially Mr. Wm. S. Cloud for assistance in preparing the tables and figures used in this summary.

TABLE 1.—*Number of observations on which are based the mean values given in Tables 4, 6, and 7.*

Altitude above M. S. L.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Spring.	Summer.	Autumn.	Winter.	Annual.
m.																	
396	90	75	89	87	89	82	83	86	85	84	106	118	265	251	275	283	1,074
500	89	75	89	87	89	82	83	86	85	84	106	118	265	251	275	282	1,073
750	89	74	88	86	89	82	82	85	85	84	105	114	263	249	274	277	1,063
1,000	89	73	86	84	86	80	80	80	84	84	100	108	256	240	268	270	1,034
1,250	85	72	84	80	83	79	76	77	82	81	97	108	247	232	260	265	1,004
1,500	84	68	80	76	75	74	75	75	79	78	94	104	231	224	251	256	962
2,000	78	60	71	65	68	62	61	62	71	68	84	91	204	185	223	229	841
2,500	68	55	64	50	56	51	52	57	56	60	69	79	170	160	185	202	717
3,000	49	48	53	37	43	44	41	46	51	49	56	65	133	131	156	162	582
3,500	33	29	32	22	25	25	35	27	39	39	38	32	79	87	116	94	376
4,000	19	14	12	11	11	14	18	13	20	11	22	15	34	45	53	48	180
4,500	3	4	1	8	5	7	7	1	10	4	8	5	14	15	22	12	63
5,000	....	3	1	3	2	1	....	....	5	....	2	2	6	1	7	5	19

TABLE 2.—*Number of observations on which are based the mean values given in Tables 8 to 11; and percentage frequency of surface winds from 16 directions.*

Surface direction.	Altitude above M. S. L. (meters).								Frequency of surface winds.
	396	500	750	1,000	2,000	3,000	4,000	5,000	%
N	112	112	111	107	84	59	20	1	8.9
NNE	61	61	61	60	40	20	5	2	4.9
NE	64	64	63	60	38	24	8	......	5.1
ENE	33	33	33	31	24	12	2	......	2.6
E	31	31	31	31	18	10	2	1	2.5
ESE	34	34	33	32	21	15	6	1	2.7
SE	68	68	68	66	53	37	13	1	5.4
SSE	99	99	99	99	85	53	22	5	7.9
S	135	135	133	132	107	75	31	3	10.7
SSW	139	139	136	135	129	95	43	6	11.1
SW	88	88	88	87	77	66	21	3	7.0
WSW	45	45	45	44	37	30	17	2	3.6
W	49	49	49	48	43	32	20	2	3.9
WNW	52	52	52	50	45	37	18	4	4.1
NW	101	101	99	97	84	67	20	2	8.0
NNW	146	146	144	142	116	72	32	9	11.6
Total	1,257	1,257	1,245	1,221	1,001	704	280	42	....

TABLE 3.—*Comparison of 24-hour surface conditions at Drexel with those during kite flights and with normal values.*

	Jan.	Feb.	Mar.	Apr.
Pressure (mb.):				
24-hour means	970.1	972.2	967.8	968.1
Departures from normal	−1.0	+1.7	−0.7	+1.4
Corrected	971.1	970.5	968.5	966.7
During kite flights	970.8	972.5	967.7	968.5
Temperature (°C.):				
24-hour means	−9.3	−5.5	4.2	8.0
Departures from normal	−1.6	+0.3	+3.2	−1.4
Corrected	−7.7	−5.8	1.0	9.4
During kite flights	−8.7	−5.3	4.9	8.6
Relative humidity %:				
Means $\frac{7\text{ a. m.}+7\text{ p. m.}}{2}$	88	84	71	71
During kite flights	83	76	61	62
Vapor pressure (mb.):				
Means $\frac{7\text{ a. m.}+7\text{ p. m.}}{2}$	2.78	3.35	5.18	6.98
During kite flights	2.86	3.55	5.04	6.93
Density (kg./cu. m.):				
Normal values	1.274	1.264	1.229	1.189
During kite flights	1.278	1.264	1.210	1.195
Wind direction:				
24-hour means	N. 56° W.	N. 48° W.	N. 7° W.	N. 36° E.
Wind velocity (m. p. s.):				
24-hour means	5.5	5.1	6.0	5.8
Sunshine (percentage of possible)	60	69	65	52
Mean cloudiness %	56	52	55	70

TABLE 3.—*Comparison of 24-hour surface conditions at Drexel with those during kite flights and with normal values*—Continued.

	May.	June.	July.	Aug.
Pressure (mb.):				
24-hour means	965.3	966.6	968.3	968.4
Departures from normal	−1.0	+0.3	−0.3	+0.3
Corrected	966.3	966.3	968.6	968.1
During kite flights	965.5	967.0	968.5	968.9
Temperature (°C.):				
24-hour means	15.9	20.5	25.2	23.4
Departures from normal	−0.4	−0.4	+1.4	+0.8
Corrected	16.3	20.9	23.8	22.6
During kite flights	17.5	21.4	26.7	23.8
Relative humidity %:				
Means $\frac{7\ a.m.+7\ p.m.}{2}$	67	70	66	70
During kite flights	58	63	58	64
Vapor pressure (mb.):				
Means $\frac{7\ a.m.+7\ p.m.}{2}$	11.65	16.63	20.18	18.39
During kite flights	11.77	16.01	19.91	18.27
Density (kg./cu. m.):				
Normal values	1.158	1.138	1.128	1.132
During kite flights	1.152	1.137	1.117	1.129
Wind direction:				
24-hour means	S. 27° E.	N. 88° E.	S. 43° E.	S. 35° E.
Wind velocity (m. p. s.):				
24-hour means	5.8	4.5	4.0	4.0
Sunshine (percentage of possible)	65	77	84	72
Mean cloudiness %	53	39	32	41

	Sept.	Oct.	Nov.	Dec.
Pressure (mb.):				
24-hour means	970.4	969.3	970.2	970.1
Departures from normal	+2.0	+0.7	0.0	−0.3
Corrected	968.4	968.6	970.2	970.4
During kite flights	970.8	969.7	970.5	969.8
Temperature (°C.):				
24-hour means	17.2	10.4	4.8	−4.6
Departures from normal	−0.9	−0.3	+3.0	−0.3
Corrected	18.1	10.7	1.8	−4.3
During kite flights	17.7	11.1	5.3	−4.0
Relative humidity %:				
Means $\frac{7\ a.m.+7\ p.m.}{2}$	71	69	76	85
During kite flights	61	57	68	79
Vapor pressure (mb.):				
Means $\frac{7\ a.m.+7\ p.m.}{2}$	12.63	7.89	6.16	3.83
During kite flights	12.57	7.63	6.22	3.80
Density (kg/cu. m.):				
Normal values	1.153	1.186	1.227	1.256
During kite flights	1.158	1.185	1.212	1.254
Wind direction:				
24-hour means	S. 29° E.	N. 76° W.	W.	N. 72° W.
Wind velocity (m. p. s.):				
24-hour means	4.2	5.0	5.1	5.0
Sunshine (percentage of possible)	70	58	60	47
Mean cloudiness %	42	52	46	61

	Spring.	Summer.	Autumn.	Winter.	Annual.
Pressure (mb.):					
24-hour means	967.1	967.8	970.0	970.8	968.9
Departures from normal	−0.1	+0.1	+0.9	+0.1	+0.3
Corrected	967.2	967.7	969.1	970.7	968.6
During kite flights	967.2	968.1	970.3	971.0	969.2
Temperature (°C.):					
24-hour means	9.4	23.0	10.8	−6.5	9.2
Departures from normal	+0.5	+0.6	+0.6	−0.5	+0.3
Corrected	8.9	22.4	10.2	−6.0	8.9
During kite flights	10.3	24.0	11.4	−6.0	9.8
Relative humidity %:					
Means $\frac{7\ a.m.+7\ p.m.}{2}$	70	69	72	86	74
During kite flights	60	62	62	79	66
Vapor pressure (mb.):					
Means $\frac{7\ a.m.+7\ p.m.}{2}$	7.94	18.40	8.89	3.32	9.64
During kite flights	7.91	18.06	8.81	3.40	9.55
Density (kg./cu. m.):					
Normal values	1.191	1.133	1.188	1.265	1.193
During kite flights	1.185	1.128	1.184	1.265	1.189
Wind direction:					
24-hour means	N. 61° E.	S. 56° E.	S. 67° W.	N. 57° W.	N. 83° W.
During kite flights	N. 55° W.	S. 5° E.	S. 61° W.	N. 68° W.	S. 78° W.
Wind velocity (m. p. s.):					
24-hour means	5.9	4.2	4.8	5.2	5.0
During kite flights	6.9	5.2	5.7	5.8	5.9
Sunshine (percentage of possible)	61	78	63	50	65
Mean cloudiness %	50	37	47	56	50

TABLE 4.—*Mean free-air barometric and vapor pressures, temperatures, relative humidities, and densities at Drexel, Nebr.*

JANUARY.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	763.1	1,017.4	− 8.3	....	89	2.36	3.14	103.4	1.337
396	728.2	970.8	− 8.7	....	83	2.15	2.86	98.8	1.278
500	718.6	958.0	− 8.9	0.19	81	2.03	2.71	97.6	1.262
750	695.8	927.6	− 8.9	0.00	77	1.85	2.47	94.5	1.222
1,000	673.6	898.1	− 7.8	−0.44	73	1.85	2.46	91.1	1.178
1,250	652.4	869.8	− 6.9	−0.36	70	1.82	2.43	88.0	1.138
1,500	631.9	842.4	− 6.7	−0.08	68	1.79	2.39	85.1	1.101
2,000	592.7	790.2	− 7.1	0.08	64	1.67	2.22	80.0	1.034
2,500	555.9	741.2	− 8.8	0.34	62	1.43	1.90	75.5	0.976
3,000	521.2	694.9	−11.0	0.44	63	1.23	1.63	71.4	0.923
3,500	488.2	650.9	−13.1	0.42	62	1.05	1.40	67.4	0.872
4,000	457.1	609.4	−15.5	0.48	60	0.88	1.17	63.7	0.824
4,500	427.6	570.1	−18.2	0.54	59	0.78	1.04	60.2	0.779

FEBRUARY.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
0	764.3	1,019.0	− 5.0	....	85	3.14	4.19	102.3	1.322
396	729.4	972.5	− 5.3	....	76	2.66	3.55	97.8	1.264
500	719.8	959.7	− 5.5	0.19	74	2.50	3.38	96.5	1.248
750	697.3	929.6	− 5.5	0.00	69	2.30	3.07	93.5	1.209
1,000	675.3	900.3	− 4.7	−0.32	64	2.21	2.94	90.3	1.167
1,250	654.3	872.3	− 3.6	−0.44	60	2.15	2.86	87.1	1.127
1,500	634.0	845.3	− 3.5	−0.04	57	1.98	2.64	84.4	1.092
2,000	597.6	793.7	− 4.1	0.12	54	1.70	2.26	79.4	1.027
2,500	558.8	745.0	− 6.0	0.38	52	1.38	1.84	75.1	0.971
3,000	524.4	699.2	− 8.5	0.50	53	1.12	1.49	71.2	0.920
3,500	491.9	655.8	−11.3	0.56	54	0.89	1.18	67.5	0.872
4,000	461.3	615.0	−14.3	0.60	54	0.66	0.88	64.0	0.828
4,500	432.9	577.2	−17.9	0.72	56	0.52	0.69	60.9	0.788
5,000	405.6	540.7	−21.8	0.78	55	0.44	0.58	58.0	0.750

MARCH.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
0	758.9	1,011.8	6.9	....	63	4.43	5.90	97.2	1.256
396	725.8	967.7	4.9	....	61	3.78	5.04	93.6	1.210
500	716.6	955.4	4.3	0.58	60	3.59	4.78	92.6	1.198
750	694.9	926.4	3.2	0.44	58	3.24	4.32	90.2	1.166
1,000	673.6	898.1	2.7	0.20	55	2.88	3.84	87.6	1.133
1,250	653.2	870.8	2.6	0.04	50	2.57	3.42	85.0	1.099
1,500	633.3	844.3	2.3	0.12	46	2.36	3.05	82.5	1.067
2,000	595.2	793.6	0.5	0.36	44	1.98	2.54	78.1	1.010
2,500	559.3	745.7	− 1.9	0.48	44	1.62	2.16	74.0	0.957
3,000	525.3	700.4	− 4.6	0.54	47	1.36	1.81	70.2	0.908
3,500	493.0	657.3	− 7.3	0.54	47	1.11	1.48	66.6	0.861
4,000	462.6	616.8	− 9.7	0.48	47	0.90	1.20	63.1	0.816
4,500	433.5	578.0	−13.5	0.76	61	0.74	0.99	60.0	0.775
5,000	405.8	541.0	−16.9	0.68	54	0.28	0.37	56.9	0.736

APRIL.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
0	761.2	1,014.9	11.8	....	62	6.05	8.07	95.7	1.238
396	726.4	968.5	8.6	....	62	5.20	6.93	92.4	1.195
500	717.2	956.2	7.7	0.87	62	4.96	6.61	91.5	1.184
750	695.8	927.6	5.7	0.80	63	4.42	5.89	89.4	1.157
1,000	674.8	899.6	4.3	0.56	62	3.97	5.29	87.2	1.128
1,250	654.4	872.5	3.0	0.52	62	3.62	4.83	85.0	1.099
1,500	634.6	846.1	1.9	0.44	61	3.33	4.44	82.8	1.070
2,000	596.4	795.2	− 0.3	0.44	60	2.70	3.60	78.4	1.014
2,500	560.4	747.1	− 2.7	0.48	58	2.08	2.77	74.4	0.962
3,000	526.2	701.6	− 5.3	0.52	58	1.66	2.21	70.5	0.912
3,500	494.1	658.7	− 8.2	0.58	59	1.28	1.71	67.0	0.866
4,000	462.7	617.9	−11.4	0.64	60	0.93	1.24	63.6	0.822
4,500	434.2	578.9	−14.5	0.62	60	0.62	0.83	60.3	0.780
5,000	406.4	541.8	−17.6	0.62	57	0.38	0.50	57.1	0.739

MAY.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
0	757.6	1,010.0	20.4	....	59	10.12	13.49	92.3	1.193
396	724.2	965.5	17.5	....	58	8.83	11.77	89.1	1.152
500	715.3	953.6	16.8	0.67	57	8.42	11.22	88.3	1,141
750	694.5	925.9	14.9	0.76	57	7.63	10.17	86.3	1.116
1,000	674.2	898.8	13.4	0.60	57	6.93	9.24	84.2	1.089
1,250	654.4	872.5	11.9	0.60	57	6.24	8.32	82.2	1.063
1,500	635.2	846.8	10.4	0.60	56	5.53	7.37	80.2	1.037
2,000	598.0	797.3	7.5	0.58	54	4.31	5.75	76.4	0.988
2,500	562.8	750.4	4.4	0.62	53	3.43	4.57	72.7	0.940
3,000	529.5	705.9	1.1	0.66	53	2.68	3.57	69.2	0.895
3,500	497.6	663.4	− 2.0	0.62	52	2.09	2.79	65.8	0.851
4,000	467.4	623.1	− 5.1	0.62	53	1.70	2.27	62.6	0.809
4,500	438.6	584.8	− 8.1	0.60	55	1.37	1.83	59.4	0.768
5,000	411.6	548.8	−11.6	0.70	59	1.01	1.35	56.5	0.731

TABLE 4.—*Mean free-air barometric and vapor pressures, temperatures, relative humidities, and densities at Drexel, Nebr.*—Continued.

JUNE.

Altitude, M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	757.8	1,010.3	24.1	....	66	14.67	19.56	91.0	1.176
396	725.3	967.0	21.4	....	63	12.01	16.01	87.9	1.137
500	716.7	955.5	20.6	0.77	61	11.17	14.89	87.2	1.127
750	696.2	928.2	18.9	0.68	59	9.65	12.86	85.2	1.102
1,000	676.2	901.5	17.4	0.60	59	8.72	11.63	83.2	1.076
1,250	656.7	875.5	16.1	0.52	58	7.73	10.31	81.2	1.050
1,500	637.6	850.1	14.9	0.48	55	6.78	9.04	79.2	1.025
2,000	600.9	801.1	12.0	0.58	52	5.30	7.07	75.5	0.976
2,500	565.9	754.5	8.8	0.64	53	4.42	5.89	71.9	0.930
3,000	532.8	710.3	5.8	0.60	51	3.53	4.71	68.5	0.885
3,500	501.2	668.2	2.5	0.66	49	2.75	3.66	65.2	0.843
4,000	471.1	628.1	− 0.7	0.64	48	2.06	2.74	62.0	0.802
4,500	442.5	589.9	− 3.8	0.58	47	1.37	1.83	59.0	0.763
5,000	415.5	554.0	− 7.6	0.78	47	0.63	0.84	56.2	0.727

JULY.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	758.7	1,011.5	29.6	....	61	17.41	23.21	89.3	1.154
396	726.4	968.5	26.7	....	58	14.93	19.91	86.4	1.117
500	717.8	957.0	25.9	0.77	57	14.23	18.97	85.6	1.107
750	697.7	930.2	24.2	0.68	56	12.79	17.05	83.7	1.083
1,000	678.0	903.9	22.5	0.68	56	11.57	15.43	81.9	1.059
1,250	659.5	878.3	20.8	0.68	56	10.55	14.06	80.0	1.035
1,500	640.0	853.3	19.2	0.64	56	9.47	12.63	78.2	1.012
2,000	604.2	805.5	15.8	0.68	56	7.58	10.11	74.8	0.967
2,500	569.7	759.6	12.2	0.72	56	6.20	8.27	71.5	0.924
3,000	536.9	715.8	8.6	0.72	56	4.91	6.55	68.2	0.882
3,500	505.5	673.9	5.1	0.70	56	3.90	5.20	65.1	0.842
4,000	476.1	634.7	1.8	0.66	56	3.16	4.21	62.1	0.803
4,500	447.7	596.9	− 1.5	0.66	55	2.49	3.32	59.1	0.764

AUGUST.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	758.5	1,011.2	25.8	....	69	16.28	21.70	90.4	1.169
396	726.7	968.9	23.8	....	64	13.70	18.27	87.3	1.129
500	717.8	957.2	23.3	0.48	62	13.00	17.33	86.4	1.118
750	697.7	930.2	22.0	0.52	59	11.47	15.29	84.4	1.092
1,000	677.8	903.7	20.9	0.44	57	10.29	13.72	82.4	1.065
1,250	658.6	878.0	19.7	0.48	55	9.31	12.40	80.4	1.039
1,500	639.7	852.9	18.3	0.56	54	8.39	11.16	78.5	1.015
2,000	603.4	804.5	15.0	0.66	55	7.03	9.35	74.9	0.969
2,500	568.8	758.3	11.4	0.72	58	5.90	7.85	71.6	0.925
3,000	535.8	714.3	7.7	0.74	60	4.82	6.41	68.3	0.883
3,500	504.3	672.3	4.1	0.72	60	3.77	5.01	65.2	0.843
4,000	474.3	632.4	0.7	0.68	57	2.72	3.61	62.1	0.803
4,500	446.1	594.8	− 2.8	0.70	53	1.82	2.41	59.2	0.766

SEPTEMBER.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	761.4	1,015.1	19.9	....	66	10.51	14.01	92.9	1.201
396	728.2	970.8	17.7	....	61	9.43	12.57	89.5	1.158
500	719.5	959.2	17.3	0.38	59	9.08	12.10	88.6	1.146
750	698.6	931.4	15.8	0.60	58	8.15	10.86	86.5	1.119
1,000	678.3	904.3	14.5	0.52	57	7.41	9.88	84.4	1.091
1,250	658.6	878.0	13.3	0.48	56	6.56	8.75	82.3	1.064
1,500	639.3	852.3	12.1	0.48	55	5.90	7.87	80.3	1.038
2,000	602.2	802.9	9.3	0.56	54	4.79	6.38	76.4	0.988
2,500	566.9	755.8	6.4	0.58	53	3.77	5.02	72.7	0.940
3,000	533.1	710.8	3.6	0.56	51	2.97	3.96	69.1	0.893
3,500	501.3	668.4	0.9	0.54	49	2.27	3.03	65.6	0.849
4,000	471.1	628.1	− 2.0	0.58	49	1.87	2.49	62.3	0.806
4,500	442.5	589.9	− 5.1	0.62	52	1.49	1.99	59.2	0.766
5,000	415.7	554.2	− 7.9	0.56	54	1.14	1.52	56.2	0.727

OCTOBER.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	761.8	1,015.6	12.8	....	60	6.50	8.67	95.4	1.234
396	727.3	969.7	11.1	....	57	5.72	7.63	91.7	1.185
500	718.3	957.6	10.6	0.48	56	5.55	7.40	90.7	1.173
750	697.0	929.3	9.5	0.44	55	5.06	6.74	88.4	1.143
1,000	676.3	901.6	8.5	0.40	53	4.63	6.17	86.1	1.113
1,250	656.3	875.0	7.7	0.32	50	4.21	5.61	83.8	1.083
1,500	636.7	848.8	6.8	0.36	51	3.96	5.28	81.5	1.054
2,000	598.9	798.5	4.8	0.40	53	3.54	4.72	77.3	0.999
2,500	563.6	751.4	2.2	0.52	55	3.06	4.08	73.4	0.949
3,000	529.8	706.4	− 0.5	0.54	54	2.55	3.40	69.7	0.902
3,500	497.9	663.8	− 3.0	0.50	53	2.06	2.74	66.1	0.855
4,000	467.4	623.1	− 5.5	0.50	50	1.62	2.16	62.7	0.810
4,500	438.6	584.7	− 7.4	0.38	47	1.35	1.80	59.2	0.766

NOVEMBER.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	763.5	1,017.9	5.4	....	76	5.33	7.11	98.3	1.270
396	727.9	970.5	5.3	....	68	4.67	6.22	93.7	1.212
500	718.7	958.2	5.3	0.00	65	4.49	5.99	92.6	1.197
750	697.1	929.4	4.9	0.16	61	4.13	5.50	89.9	1.162
1,000	676.0	901.3	4.6	0.12	56	3.69	4.92	87.3	1.129
1,250	655.6	874.1	4.1	0.20	53	3.44	4.59	84.8	1.097
1,500	635.8	847.6	3.5	0.24	51	3.15	4.20	82.4	1.066
2,000	597.6	796.7	1.6	0.38	48	2.54	3.39	78.0	1.009
2,500	561.6	748.7	− 0.8	0.48	47	2.07	2.76	74.0	0.957
3,000	527.4	703.1	− 3.7	0.58	47	1.73	2.31	70.3	0.908
3,500	494.8	659.7	− 6.5	0.56	48	1.44	1.92	66.6	0.862
4,000	464.0	618.6	− 9.4	0.58	48	1.14	1.52	63.2	0.816
4,500	434.5	579.3	−12.1	0.54	42	0.83	1.10	59.8	0.773
5,000	407.7	543.6	−15.0	0.58	35	0.53	0.70	56.7	0.734

TABLE 4.—*Mean free-air barometric and vapor pressures, temperatures, relative humidities, and densities at Drexel, Nebr.*—Continued.

DECEMBER.

Altitude. M. S. L.	Pressure.		Temperature.		Relative humidity.	Vapor pressure.		Density.	
m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	763.7	1,018.2	− 4.5	....	88	3.16	4.21	102.0	1.319
396	727.4	969.8	− 4.0	....	79	2.85	3.80	97.0	1.254
500	710.4	957.1	− 3.8	− 0.19	76	2.72	3.63	95.6	1.237
750	695.6	927.4	− 3.6	− 0.08	71	2.56	3.41	92.6	1.198
1,000	673.9	898.5	− 3.0	− 0.24	66	2.43	3.24	89.5	1.158
1,250	653.0	870.6	− 2.6	− 0.16	60	2.24	2.98	86.6	1.120
1,500	632.8	843.6	− 2.9	0.12	58	2.06	2.74	84.1	1.087
2,000	594.0	792.0	− 4.2	0.26	54	1.70	2.26	79.3	1.025
2,500	557.4	743.2	− 6.3	0.38	53	1.39	1.85	75.0	0.970
3,000	522.9	697.1	− 8.7	0.48	54	1.14	1.52	71.0	0.918
3,500	490.2	653.6	−11.1	0.48	55	0.92	1.23	67.2	0.869
4,000	459.5	612.6	−13.7	0.52	55	0.72	0.96	63.6	0.822
4,500	430.6	574.1	−16.4	0.54	56	0.48	0.64	60.3	0.779
5,000	403.5	537.9	−18.9	0.50	56	0.29	0.39	57.0	0.737

SPRING.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	759.2	1,012.2	13.0	....	61	6.86	9.15	95.0	1.229
396	725.4	967.2	10.3	....	60	5.93	7.91	91.7	1.185
500	716.3	955.0	9.6	0.67	59	5.65	7.53	90.8	1.174
750	695.0	926.6	7.9	0.68	59	5.09	6.79	88.6	1.146
1,000	674.1	898.8	6.8	0.44	58	4.59	6.12	86.3	1.116
1,250	653.9	871.9	5.8	0.40	56	4.14	5.52	84.0	1.086
1,500	634.3	845.7	4.8	0.40	54	3.71	4.95	81.8	1.058
2,000	596.5	795.3	2.5	0.46	52	2.97	3.96	77.6	1.004
2,500	560.7	747.6	− 0.2	0.54	51	2.37	3.16	73.7	0.953
3,000	526.9	702.5	− 3.0	0.56	52	1.89	2.52	70.0	0.905
3,500	494.7	659.6	− 5.9	0.58	52	1.49	1.98	66.5	0.860
4,000	464.3	619.1	− 8.8	0.58	53	1.17	1.56	63.1	0.816
4,500	435.3	580.4	−12.1	0.46	58	0.90	1.20	59.9	0.774
5,000	407.8	543.7	−15.4	0.66	56	0.54	0.72	56.8	0.735

SUMMER.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	757.5	1,010.0	26.5	....	65	16.12	21.49	90.1	1.165
396	726.1	968.1	24.0	....	62	13.55	18.06	87.2	1.128
500	717.4	956.5	23.3	0.67	60	12.80	17.06	86.4	1.117
750	697.1	929.5	21.7	0.64	58	11.30	15.06	84.5	1.092
1,000	677.3	903.0	20.3	0.56	57	10.19	13.59	82.5	1.066
1,250	657.9	877.2	18.9	0.56	56	9.19	12.25	80.5	1.041
1,500	639.0	852.0	17.5	0.56	55	8.21	10.94	78.6	1.017
2,000	602.7	803.6	14.3	0.64	54	6.63	8.84	75.1	0.970
2,500	568.1	757.4	10.8	0.70	56	5.50	7.33	71.6	0.926
3,000	535.1	713.4	7.4	0.68	56	4.41	5.88	68.3	0.883
3,500	503.6	671.4	4.0	0.68	56	3.46	4.61	65.2	0.842
4,000	473.7	631.6	0.7	0.66	55	2.63	3.50	62.0	0.802
4,500	445.3	593.7	− 2.6	0.66	53	1.88	2.50	59.1	0.764
5,000	418.3	557.7	− 6.4	0.76	51	1.06	1.41	56.3	0.728

AUTUMN.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	762.2	1,016.2	12.7	....	67	7.45	9.93	95.5	1.235
396	727.7	970.3	11.4	....	62	6.61	8.81	91.6	1.184
500	718.7	958.3	11.1	0.20	60	6.38	8.50	90.6	1.171
750	697.5	930.0	10.1	0.40	58	5.78	7.70	88.2	1.141
1,000	676.8	902.4	9.2	0.36	55	5.24	6.99	85.9	1.111
1,250	656.8	875.7	8.4	0.32	53	4.74	6.32	83.6	1.081
1,500	637.2	849.6	7.5	0.36	52	4.34	5.79	81.4	1.052
2,000	600.0	799.4	5.3	0.44	51	3.63	4.84	77.2	0.998
2,500	564.0	752.0	2.6	0.54	51	2.97	3.96	73.4	0.948
3,000	530.1	706.8	− 0.2	0.56	50	2.42	3.23	69.7	0.901
3,500	498.0	664.0	− 2.8	0.52	49	1.93	2.57	66.1	0.855
4,000	467.5	623.3	− 5.6	0.56	48	1.55	2.06	62.7	0.811
4,500	438.5	584.6	− 8.2	0.52	46	1.22	1.63	59.4	0.768
5,000	411.8	549.1	−11.0	0.56	43	0.92	1.22	56.4	0.730

WINTER.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	763.7	1,018.2	− 5.9	....	87	2.89	3.85	102.5	1.326
396	728.3	971.0	− 6.0	....	79	2.55	3.40	97.8	1.265
500	718.7	958.2	− 6.1	0.10	77	2.43	3.24	96.6	1.249
750	696.1	928.1	− 6.0	−0.04	72	2.24	2.98	93.5	1.210
1,000	674.2	898.9	− 5.2	−0.32	67	2.16	2.88	90.3	1.168
1,250	653.1	870.8	− 4.4	−0.32	63	2.07	2.76	87.2	1.128
1,500	632.8	843.7	− 4.4	0.00	61	1.94	2.59	84.5	1.093
2,000	593.9	791.9	− 5.1	0.14	57	1.69	2.25	79.6	1.029
2,500	557.3	743.1	− 7.0	0.42	55	1.40	1.86	75.2	0.972
3,000	522.8	697.0	− 9.4	0.48	56	1.16	1.54	71.2	0.920
3,500	490.0	653.3	−11.8	0.48	56	0.95	1.26	67.3	0.871
4,000	459.2	612.2	−14.5	0.54	56	0.74	0.99	63.8	0.824
4,500	430.3	573.7	−17.5	0.60	57	0.59	0.78	60.5	0.782
5,000	403.1	537.4	−20.7	0.64	57	0.46	0.61	57.4	0.742

ANNUAL.

m.	mm.	mb.	°C.	Δt/100m.	%	mm.	mb.	%	kg./m.³
0	760.8	1,014.4	11.6	....	70	8.33	11.10	95.6	1.237
396	726.9	969.2	9.8	....	66	7.16	9.55	92.0	1.180
500	717.8	957.1	9.4	0.38	64	6.82	9.09	91.0	1.170
750	696.5	928.6	8.4	0.40	62	6.11	8.14	88.6	1.146
1,000	675.6	900.8	7.8	0.24	60	5.55	7.40	86.2	1.114
1,250	655.4	873.9	7.2	0.24	58	5.04	6.72	83.8	1.083
1,500	635.8	847.7	6.4	0.32	56	4.55	6.07	81.5	1.054
2,000	598.1	797.5	4.2	0.44	54	3.73	4.97	77.3	1.000
2,500	562.5	750.0	1.5	0.54	54	3.06	4.08	73.5	0.950
3,000	528.7	704.9	− 1.3	0.56	54	2.47	3.30	69.8	0.902
3,500	496.5	662.0	− 4.1	0.56	54	1.97	2.62	66.2	0.856
4,000	466.1	621.5	− 7.0	0.58	54	1.52	2.05	62.9	0.813
4,500	437.3	583.1	−10.1	0.62	55	1.17	1.56	59.7	0.772
5,000	410.2	546.9	−13.3	0.64	54	0.80	1.06	56.7	0.733

TABLE 5.—*Average summer, winter, and annual densities, kilograms per cubic meter, in different parts of the world.*

Altitude, M. S. L.	Standard (9).	Drexel.			Mount Weather (7).		
	Annual.	Summer.	Winter.	Annual.	Summer.	Winter.	Annual.
m.							
0	1.221	1.165	1.326	1.237	1.173	1.296	1.226
500	1.161	1.117	1.249	1.176	1.124	1.226	1.171
1,000	1.104	1.066	1.168	1.114	1.076	1.155	1.113
1,500		1.017	1.093	1.054	1.027	1.089	1.057
2,000	0.996	0.970	1.029	1.000	0.979	1.026	1.002
2,500		0.926	0.972	0.950	0.932	0.970	0.951
3,000	0.896	0.883	0.920	0.902	0.887	0.918	0.903
3,500		0.842	0.871	0.856	0.845	0.871	0.858
4,000	0.808	0.802	0.824	0.813	0.805	0.828	0.816
4,500		0.764	0.782	0.772	0.765	0.789	0.775
5,000	0.729	0.728	0.742	0.733	0.726	0.728	0.731
6,000	0.654						
7,000	0.587						
8,000	0.525						
9,000	0.468						
10,000	0.415						

Altitude, M. S. L.	Canada (10).	England (10).	Europe. (10).	Equator (10).	Northeastern France (8).	
	Annual.	Annual.	Annual.	Annual.	Summer.	Winter.
m.						
0	1.258	1.253	1.258	1.174	1.224	1.288
500					1.159	1.212
1,000	1.134	1.128	1.128	1.067	1.100	1.147
1,500					1.046	1.084
2,000	1.011	1.014	1.017	0.968	0.995	1.025
2,500					0.946	0.970
3,000	0.905	0.909	0.913	0.871	0.898	0.920
3,500						
4,000	0.815	0.819	0.819	0.789	0.808	0.827
4,500						
5,000	0.733	0.735	0.735	0.714	0.727	0.743
6,000	0.662	0.658	0.661	0.645	0.653	0.666
7,000	0.592	0.589	0.590	0.581	0.587	0.596
8,000	0.528	0.524	0.528	0.522	0.527	0.530
9,000	0.470	0.463	0.467	0.469	0.472	0.469
10,000	0.415	0.409	0.411	0.419	0.419	0.410

TABLE 6.—*Mean free-air winds at Drexel, Nebr.*

Altitude, M. S. L.	Spring.		Summer.	
	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*
396	N. 55° W.	6.9	S. 5° E.	5.2
500	N. 58° W.	8.7	S. 1° E.	7.3
750	N. 64° W.	12.0	S. 11° W.	10.5
1,000	N. 83° W.	12.8	S. 25° W.	10.9
1,250	S. 81° W.	13.1	S. 44° W.	10.9
1,500	S. 79° W.	13.2	S. 55° W.	10.8
2,000	S. 81° W.	13.4	S. 64° W.	11.0
2,500	S. 85° W.	13.9	S. 74° W.	11.3
3,000	S. 82° W.	14.9	S. 79° W.	11.9
3,500	N. 89° W.	16.3	S. 79° W.	12.3
4,000	N. 88° W.	17.8	S. 77° W.	12.7
4,500	S. 82° W.	19.5	S. 82° W.	13.8
5,000	W.	20.8	S. 87° W.	15.0

Altitude, M. S. L.	Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*		*m. p. s.*
396	S. 61° W.	5.7	N. 68° W.	5.8	S. 78° W.	5.9
500	S. 70° W.	8.1	N. 67° W.	8.0	S. 81° W.	8.0
750	S. 80° W.	12.0	N. 65° W.	11.8	S. 84° W.	11.6
1,000	S. 83° W.	13.0	N. 66° W.	12.9	S. 81° W.	12.4
1,250	S. 88° W.	13.5	N. 70° W.	13.6	S. 81° W.	12.8
1,500	N. 89° W.	13.5	N. 70° W.	14.1	S. 84° W.	12.9
2,000	S. 89° W.	13.6	N. 75° W.	15.3	S. 85° W.	13.3
2,500	W.	14.3	N. 76° W.	16.7	S. 88° W.	14.0
3,000	N. 86° W.	15.0	N. 79° W.	18.1	S. 89° W.	15.0
3,500	N. 85° W.	15.5	N. 80° W.	19.8	N. 89° W.	16.0
4,000	N. 84° W.	16.3	N. 79° W.	21.7	W.	17.1
4,500	N. 76° W.	17.5	N. 84° W.	23.0	N. 89° W.	18.4
5,000	N. 80° W.	18.5	N. 76° W.	24.2	N. 85° W.	19.6

TABLE 7.—*Resultant free-air winds at Drexel, Nebr.*

Altitude, M. S. L.	Spring.		Summer.	
	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*
396	S. 10° W.	0.7	S. 13° W.	1.6
500	S. 21° W.	0.8	S. 4° W.	2.2
750	S. 68° W.	1.0	S. 17° W.	3.1
1,000	S. 69° W.	1.7	S. 40° W.	3.1
1,250	S. 74° W.	2.5	S. 50° W.	3.8
1,500	S. 74° W.	3.6	S. 58° W.	4.6
2,000	S. 80° W.	5.5	S. 69° W.	6.4
2,500	S. 83° W.	7.6	S. 80° W.	7.7
3,000	S. 84° W.	10.4	S. 81° W.	8.9
3,500	S. 89° W.	12.4	S. 81° W.	9.7
4,000	N. 88° W.	14.7	S. 84° W.	9.3
4,500	N. 81° W.	14.7	S. 87° W.	9.9
5,000	N. 89° W.	16.1	N. 82° W.	13.7

Altitude, M. S. L.	Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
m.		*m. p. s.*		*m. p. s.*		*m. p. s.*
396	S. 56° W.	1.2	N. 70° W.	1.5	S. 51° W.	0.9
500	S. 60° W.	1.6	N. 69° W.	2.2	S. 55° W.	1.2
750	S. 89° W.	2.9	N. 66° W.	4.3	S. 72° W.	2.2
1,000	S. 76° W.	3.6	N. 67° W.	5.6	S. 83° W.	3.1
1,250	S. 78° W.	4.5	N. 71° W.	6.7	S. 84° W.	4.1
1,500	S. 80° W.	5.5	N. 72° W.	8.0	S. 88° W.	5.2
2,000	N. 89° W.	6.8	N. 75° W.	10.4	W.	7.1
2,500	N. 86° W.	8.6	N. 78° W.	13.2	N. 88° W.	9.3
3,000	N. 82° W.	10.0	N. 80° W.	14.9	N. 87° W.	11.1
3,500	N. 79° W.	10.9	N. 81° W.	16.8	N. 86° W.	12.4
4,000	N. 72° W.	11.7	N. 79° W.	18.3	N. 83° W.	13.0
4,500	N. 74° W.	13.6	N. 77° W.	19.3	N. 81° W.	14.2
5,000	N. 74° W.	15.8	N. 76° W.	18.3	N. 79° W.	16.3

TABLE 8.—*Average annual free-air winds at Drexel, Nebr., for different surface directions.*

Surface direction.	Altitude above M. S. L. (meters).							
	396		500		750		1,000	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
		m. p. s.		*m. p. s.*		*m. p. s.*		*m. p. s.*
N	N.	4.8	N.	7.0	N.	10.9	N. 2° W.	11.8
NNE	NNE.	5.0	N. 21° E.	6.8	N. 24° E.	10.0	N. 26° E.	10.6
NE	NE.	5.2	N. 46° E.	6.8	N. 48° E.	9.2	N. 54° E.	9.8
ENE	ENE.	5.4	N. 68° E.	7.0	N. 62° E.	9.8	N. 76° E.	10.1
E	E.	6.2	S. 87° E.	8.3	S. 82° E.	10.9	S. 75° E.	10.5
ESE	ESE.	6.2	S. 64° E.	8.3	S. 50° E.	11.4	S. 39° E.	12.2
SE	SE.	5.8	S. 41° E.	8.3	S. 27° E.	11.6	S. 17° E.	12.2
SSE	SSE.	5.0	S. 19° E.	7.3	S. 11° E.	10.8	S. 3° E.	11.5
S	S.	6.2	S. 1° W.	8.6	S. 9° W.	12.7	S. 15° W.	13.4
SSW	SSW.	7.4	S. 24° W.	9.5	S. 32° W.	13.2	S. 40° W.	14.1
SW	SW.	5.7	S. 48° W.	8.7	S. 55° W.	12.0	S. 61° W.	12.3
WSW	WSW.	5.8	S. 71° W.	8.0	S. 79° W.	11.2	S. 86° W.	10.2
W	W.	5.4	N. 88° W.	7.4	N. 81° W.	10.0	N. 74° W.	10.7
WNW	WNW.	6.0	N. 67° W.	7.8	N. 62° W.	11.1	N. 60° W.	12.2
NW	NW.	5.8	N. 44° W.	8.0	N. 42° W.	11.8	N. 42° W.	13.3
NNW	NNW.	5.8	N. 22° W.	7.9	N. 24° W.	12.1	N. 26° W.	13.5

Surface direction.	Altitude above M. S. L. (meters).							
	2,000		3,000		4,000		5,000	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
		m. p. s.		*m. p. s.*		*m. p. s.*		*m. p. s.*
N	N. 17° W.	12.4	N. 41° W.	14.4	N. 58° W.	16.6	N. 68° W.	21.9
NNE	N. 16° E.	10.0	N. 20° W.	10.4	N. 47° W.	13.6	N. 45° W.	15.3
NE	N. 53° E.	8.4	N. 21° W.	10.0	N. [illegible]° W.	10.0		
ENE	S. 76° E.	8.3	S. 25° W.	10.8	S. 56° W.	7.5		
E	S. 34° E.	8.4	S. 9° E.	9.2	S. 56° W.	12.8	W.	15.7
ESE	S. 4° W.	11.9	S. 28° W.	12.4	S. 38° W.	16.2	S. 45° W.	21.8
SE	S. 14° W.	12.2	S. 43° W.	13.2	S. 82° W.	13.5	W.	27.4
SSE	S. 22° W.	11.8	S. 48° W.	12.3	S. 56° W.	13.4	S. 49° W.	12.1
S	S. 37° W.	14.2	S. 57° W.	14.8	S. 60° W.	17.3	N. 78° W.	18.3
SSW	S. 56° W.	14.0	S. 71° W.	14.8	S. 88° W.	16.4	N. 75° W.	20.9
SW	S. 77° W.	13.4	S. 88° W.	15.1	N. 89° W.	17.1	N. 79° W.	21.4
WSW	N. 88° W.	13.2	N. 87° W.	15.4	S. 84° W.	17.1	N. 79° W.	25.4
W	N. 74° W.	11.6	N. 85° W.	18.3	N. 76° W.	19.8	N. 45° W.	20.4
WNW	N. 65° W.	15.4	N. 75° W.	19.0	N. 78° W.	22.7	S. 86° W.	26.4
NW	N. 50° W.	16.4	N. 58° W.	19.2	N. 77° W.	22.0	N. 68° W.	22.3
NNW	N. 39° W.	16.4	N. 52° W.	19.2	N. 65° W.	21.8	N. 88° W.	23.8

TABLE 9.—*Average annual clockwise (CW.) or counterclockwise (CCW.) turning of winds from surface direction at Drexel, Nebr.*

Surface direction.	Altitude above M. S. L. (meters).													
	500		750		1,000		2,000		3,000		4,000		5,000	
	CW.	CCW.	CW.	CCW.	CW.	CCW.	CW.	CCW.	CW.	CCW.	CW.	CCW.	CW.	CCW.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
N	1	3	5	9	14	26	10	61	2	84	2	98	0	100
NNE	5	6	24	20	32	38	42	52	24	72	0	100	0	100
NE	5	1	21	10	38	16	52	34	35	50	30	70	.....	....
ENE	2	0	19	13	43	13	62	18	83	17	100	0	.....	....
E	14	0	32	8	41	11	88	8	100	0	100	0	100	0
ESE	16	0	50	2	78	0	100	0	100	0	100	0	100	0
SE	25	0	56	2	70	2	89	4	90	3	100	0	100	0
SSE	10	0	44	4	64	4	81	7	97	0	96	0	89	0
S	7	1	33	4	56	2	85	4	95	2	96	2	100	0
SSW	12	0	41	4	60	7	77	4	84	3	88	5	100	0
SW	12	0	33	2	50	5	74	9	82	6	83	17	100	0
WSW	17	0	41	2	62	2	77	8	71	11	78	18	100	0
W	11	0	39	3	56	6	70	16	54	22	52	14	100	0
WNW	4	0	32	8	39	13	49	30	42	47	24	49	0	100
NW	4	1	18	7	20	7	15	18	12	47	7	68	0	50
NNW	3	0	6	14	7	24	9	58	3	69	5	79	0	100
Means	8	1	28	7	51	12	56	23	58	26	60	30	56	38

TABLE 10.—*Average annual frequency of a west component in winds at various levels at Drexel, Nebr.*

Surface direction.	Altitude above M. S. L. (meters).							
	396	500	750	1,000	2,000	3,000	4,000	5,000
	%	%	%	%	%	%	%	%
N	50	52	50	55	76	90	95	100
NNE	0	2	10	17	45	75	100	100
NE	0	0	0	0	24	46	50	....
ENE	0	0	0	3	29	67	100	....
E	0	0	0	0	22	50	100	100
ESE	0	0	6	6	57	73	83	100
SE	0	0	9	24	62	73	92	100
SSE	0	6	25	41	75	94	91	80
S	50	53	64	76	90	96	97	100
SSW	100	100	99	96	97	98	95	100
SW	100	100	100	100	99	99	95	100
WSW	100	100	100	100	100	97	94	100
W	100	100	100	100	98	100	100	100
WNW	100	100	100	100	100	100	100	100
NW	100	100	99	99	100	100	100	100
NNW	100	99	97	97	96	100	100	100
Means	60	61	64	68	83	92	95	98

NOTE.—Winds recorded exactly "north" or "south" have been considered as having had a westerly component in 50% of the cases.

TABLE 11.—*Average annual frequency of north and south components in winds at various levels at Drexel, Nebr.*

Surface direction.	Altitude above M. S. L. (meters).															
	396		500		750		1,000		2,000		3,000		4,000		5,000	
	N.	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.	S.	N.	S.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
N	100	0	100	0	100	0	100	0	99	1	98	2	95	5	100	0
NNE	100	0	100	0	100	0	95	5	85	15	80	20	100	0	100	0
NE	100	0	100	0	97	3	88	12	68	32	71	29	75	25	....	....
ENE	100	0	97	3	85	15	65	35	33	67	8	92	0	100	....	....
E	50	50	39	61	39	61	32	68	11	89	0	100	0	100	0	100
ESE	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100
SE	0	100	0	100	0	100	0	100	2	98	8	92	23	77	0	100
SSE	0	100	0	100	0	100	0	100	0	100	8	92	9	91	20	80
S	0	100	0	100	0	100	0	100	4	96	9	91	26	74	67	33
SSW	0	100	0	100	0	100	1	99	9	91	24	76	47	53	67	33
SW	0	100	0	100	5	95	8	92	31	69	48	52	48	52	67	33
WSW	0	100	4	96	18	82	32	68	65	35	67	33	71	29	100	0
W	50	50	59	41	76	24	85	15	84	16	88	12	85	15	100	0
WNW	100	0	100	0	98	2	98	2	87	13	84	16	72	28	50	50
NW	100	0	100	0	100	0	99	1	99	1	93	7	75	25	100	0
NNW	100	0	100	0	100	0	100	0	97	3	93	7	75	25	67	33
Means	48	52	49	51	49	51	49	51	49	51	52	48	55	45	62	38

NOTE.—Winds recorded exactly "east" or "west" have been considered as having had a northerly component in 50 per cent of the cases, and a southerly component in the remaining 50 per cent.

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WINDS AND TEMPERATURE-GRADIENTS IN THE STRATOSPHERE.

By G. M. B. DOBSON.

[Abstract reprinted from *Nature*, Jan. 1, 1920, p. 458. Presented before Royal Meteorological Society, London, Dec. 17, 1919.]

From the results of temperature observations by *ballons-sondes*, it can be shown that the horizontal pressure-gradient, and therefore the wind velocity, should decrease rapidly on passing from the troposphere to the stratosphere. Previously there had been little confirmation of this by actual observations. Seventy ascents recorded by the international commission gave data for temperature, wind velocity, and wind direction to great heights. These showed that, almost without exception, winds of moderate or great velocity in the troposphere fall off very rapidly on entering the stratosphere, while the wind direction remained constant. On days with small pressure-gradients this effect was not usually found—a result which was to be expected, since the slope of the tropopause would then not necessarily be toward the low pressure. Horizontal pressure and temperature-gradients calculated for the observed winds on typical days with moderate or large pressure-gradients show that the pressure-gradient is suddenly reduced, and the temperature-gradient suddenly reversed, on entering the stratosphere. The temperature-gradients calculated from the observed wind velocities are in good agreement with those deduced by Mr. W. H. Dines from temperature and pressure observations.

SUNSHINE IN THE UNITED STATES.

By JOSEPH BURTON KINCER, Meteorologist.

[Dated: Weather Bureau, Washington, Jan. 17, 1920.]

SYNOPSIS.—Sunshine is a very important climatic element, not only from the standpoint of the agriculturist, but also from its physical effect on man and other animals. The depressing influence on human beings of long periods of cloudy and damp weather is noticeable, even to the casual observer, while, on the other hand, long periods of successive days with continuous sunshine and high temperature are trying on all animal and plant life. Long hot periods are usually characterized by few clouds and much sunshine, when, day after day, the amount of insolation received during the daytime results in an accumulation of heat in excess of that lost at night by radiation. Finally a change in pressure conditions results in the breaking up of the stagnant atmosphere, bringing refreshing winds and welcome clouds to relieve the situation.

Sunshine data are recorded and expressed either in values giving the actual amount in hours and tenths, or by indicating the percentage of the possible amount. Each of these methods has advantages not possessed by the other. Owing to the large seasonal variations in the possible amount, the actual duration of sunshine from month to month is not disclosed directly by a statement of the percentage of the possible. For in such case, a knowledge of the latter is necessary before the actual amount can be determined. For example, along the north-central border of the United States, a day with four hours of sunshine the latter part of December would have 50 per cent of the possible, while a like amount the latter part of June would be only 25 per cent of the possible. On the other hand, the percentage of the possible amount gives a better direct indication of the seasonal variations in cloudiness than do data showing the actual number of sunshine hours. Published sunshine data for the United States are given mostly in values showing the percentage of the possible amount.

In view of the advantages possessed by each of these methods of presenting data, they are given in this study in both values and in considerable detail. Charts and graphs are presented showing the mean solar time of sunrise and sunset, and the average length of the day, sunrise to sunset, representing the possible maximum amount of sunshine for different seasons of the year. Included is a series of charts showing for each month the average amount of sunshine in hours per day; also charts and graphs showing the seasonal and annual distribution in percentages of the possible amount. Other charts show the percentage of days clear, partly cloudy, and cloudy, while the diurnal distribution of sunshine is also graphically shown. There is included a table showing for each month and for the year the average percentage of the possible amount of sunshine for all stations where continuous automatic records are made, which include practically all regular reporting stations. The basic data are for the 20-year period from 1895 to 1914, except that the percentages of the possible amount are for the 8-year period from 1905 to 1912.

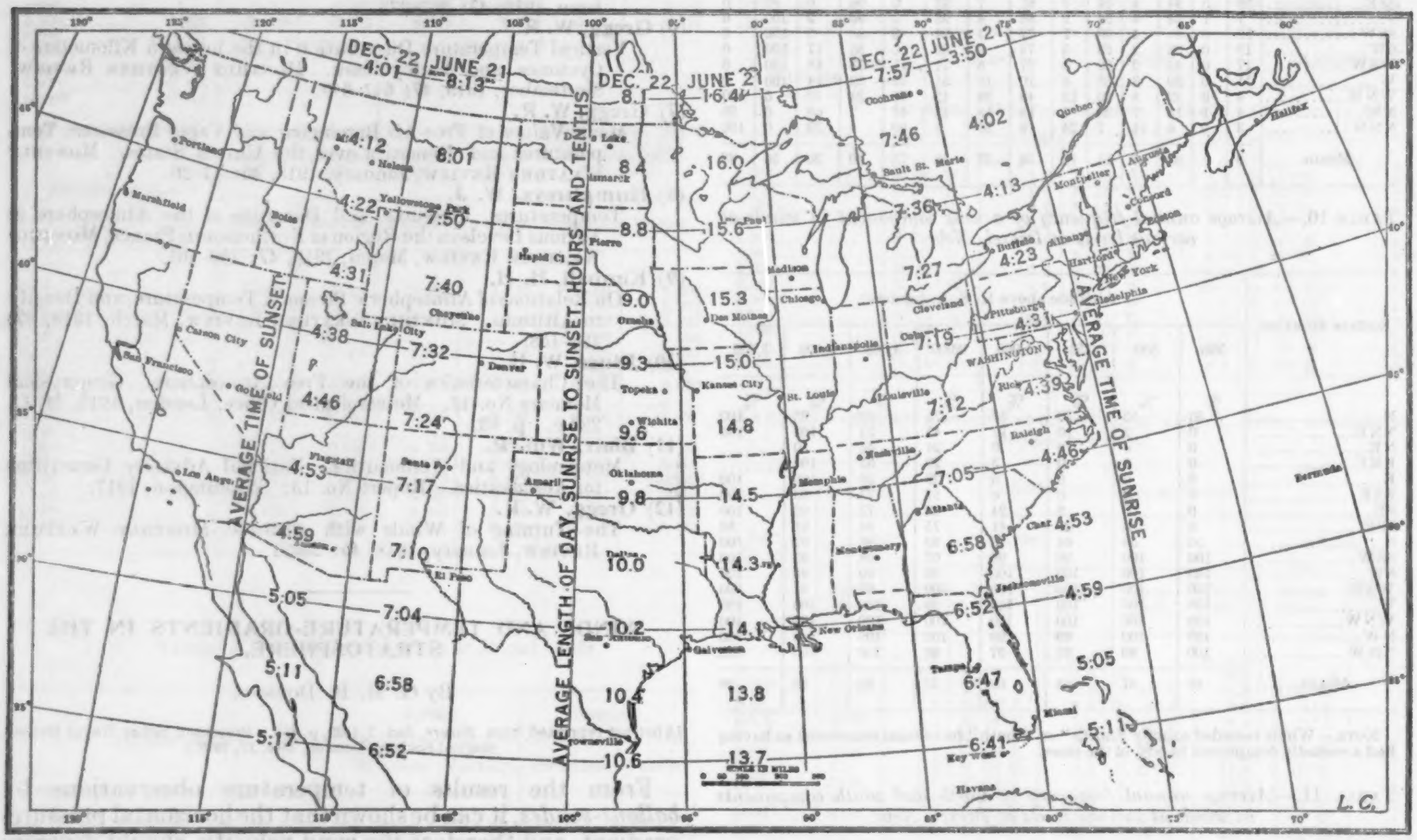


FIG. 1.—The average mean solar time of sunrise and sunset and the average length of the day, sunrise to sunset, on December 22 and June 21, for each two and one-half degrees of latitude.

VARIATIONS IN THE POSSIBLE AMOUNT OF SUNSHINE.

With an ideal sea-level horizon, the amount of sunshine received in any locality for the year as a whole would be determined by the prevailing state of the sky as to presence or absence of clouds and fog, although there is a slight increase with latitude in the possible amount of yearly sunshine. This variation is unimportant, however, amounting in the course of the year to a total of only about 35½ hours between latitudes 25° and 49° north, representing the extreme southern and extreme northern portions of the United States; the average possible yearly amount at latitude 25° is 4,437.2 hours and at latitude 49°, 4,472.6, for a 365-day year.

The possible amount of sunshine, however, has wide seasonal variation in middle and high latitudes, the variations increasing rapidly with the latitude. It varies from week to week throughout the year, being greater in higher than in lower latitudes in summer, and vice versa in win-

ter. The time of sunrise and sunset at a given place when expressed in mean solar time varies from day to day, depending upon the declination of the sun, while variations in the equation of time, the apparent diameter of the sun, and the atmospheric refraction at the points of sunrise and sunset also affect the results. Moreover, these quantities, as well as the solar declination, do not have the same values on corresponding days from year to year. It follows, then, that in a general table showing the time of sunrise and sunset, the exact time is represented only approximately, but even in extreme cases the error is not material, being only two or three minutes per day.

For comparison as to the possible amount of sunshine that could occur in different portions of the United States, and to indicate the seasonal variations in amount, figures 1 and 2 are presented. Figure 1 shows for each two and one-half degrees of latitude the average mean solar time of sunrise and sunset and the average length of the day, from sunrise to sunset, on December 22 and June 21, or the time of the winter and summer solstice, which represent the shortest and the longest days, respectively, of the year. At the time of the equinoxes, about March 21 and September 22, the days and nights are substantially of equal length, not only in all portions of the United States but throughout the world.

It will be noted from figure 1 that during the season of longest days of the year the sun rises at the northern end of a north-and-south line drawn through the center of the United States from the northern to the southern boundary about one hour earlier than at the southern end, and that this condition is reversed during the period of the shortest days of the year. Figure 2 shows the variations from month to month in the length of the day, from sunrise to sunset, at latitudes 25°, 37°, and 49°. The vertical bars to the right of this graph visualize the amplitudes of variations for the latitudes given. It will be noted that while the longest day of the year at latitude 25°, extreme southern Florida, is only about three hours longer than the shortest day, at latitude 49°, representing the northwestern boundary of the country, the longest day is eight hours longer than the shortest. The actual amount of sunshine received in different portions of the United States varies greatly, however, from these potential amounts.

REGISTRATION OF SUNSHINE.

The sunshine data collected by the Weather Bureau are not entirely satisfactory, owing to the fact that the automatic recording instruments available to the present time do not indicate the different degrees of sunshine intensity, and it is very desirable that a more satisfactory instrument be devised. There are three forms of sunshine recorders in use: These are the Campbell-Stokes burning recorder, consisting of a lens or burning glass which scorches, during bright sunshine, a trace on a strip of cardboard placed at the proper focal distance and adjusted by clockwork to revolve with the sun; the Jordan, or photographic recorder; and the electical thermometric recorder, now in general use by the Weather Bureau. The last-named instrument consists essentially of a straight glass tube with a cylindrical bulb at each end, the lower bulb, as exposed for service, being coated on on the outside with lampblack, and the whole inclosed in a protecting glass sheath, the space between the inner tube and the protecting sheath being exhausted of air and hermetically sealed. Mercury is used to separate the air in the bulbs, and two wires are inserted through the inner tube about midway between the bulbs, but above the point the top of the mercury column assumes in the absence of sunshine. The ends of the wires within the inner tube are slightly separated, but are so arranged that the electric circuit will be closed by the mercury coming in contact with them. The instrument operates by the greater expansion of the air in the lower, blackened bulb and also of the mercury in the tube, caused by the heat of the sun's rays, this expansion causing the top of the mercury column to move upward and make contact with the ends of the wires. With the cessation of sunshine, contraction causes the reverse operation and the circuit is opened. The instrument is therefore a kind of thermometer, and, owing to its somewhat sluggish action, when the sky is partly covered with floating clouds the presence or absence of sunshine for short periods may not be recorded. In general, however, the time lost should about equal that gained and the record is not thereby materially vitiated. The instrument is

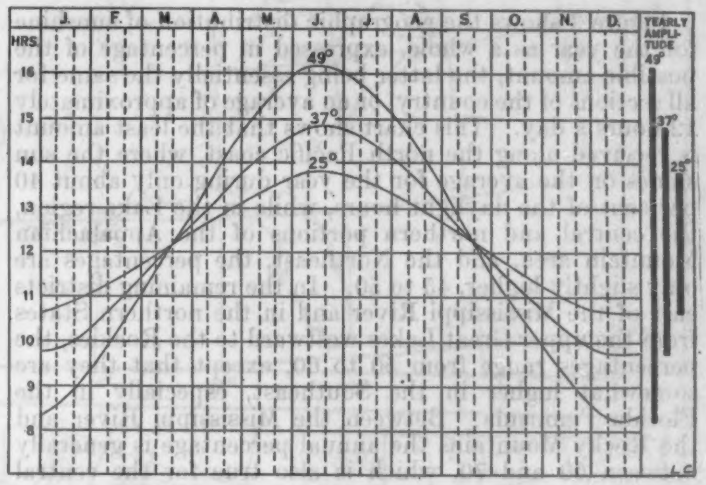


FIG. 2.—Seasonal variations in the length of the day, sunrise to sunset, at latitudes 25°, 37°, and 49°.

not delicate enough to record sunshine in the early morning immediately after the sun appears above the horizon, and likewise the sun's rays usually become too weak to maintain a record somewhat before sunset. In such cases the actual unrecorded sunshine is noted by personal observations, and the records are corrected by adding thereto, when the sun is shining, the interval between actual sunrise and the beginning of the automatic record, and that between the ending of the record and the time of actual sunset.

SUNSHINE DATA.

Sunshine data may be expressed as the number of hours of daily sunshine, or as percentage of the possible amount. When given in the latter values, the actual amount can be determined only with a knowledge of the possible amount, or that which would be received with continuously clear sky. There are included with this paper charts and tables showing the annual, seasonal, and diurnal variations of sunshine in the United States by both classes of values. The installation of automatic sunshine recorders was begun at Weather Bureau stations in the early nineties, and a few years thereafter practically all of the regular reporting stations were equipped with these instruments.[1]

There appeared in the November, 1919, MONTHLY WEATHER REVIEW **47 : 769–793**; an extensive paper, by

[1] See "Bibliographic note on sunshine in the United States," by R. DeC. Ward, MONTHLY WEATHER REVIEW, Nov., 1919, 47; 794–795.

Prof. Kimball on the variations of the total and luminous solar radiation with geographic position in the United States, in which these variations (expressed in gram-calorie units), with latitude, altitude, slope, and varying atmospheric conditions, were discussed in detail, with numerous illustrations and tables of observational and computed values. The paper here presented has a more or less direct relation to that of Prof. Kimball in so far as the actual amount of sunshine received in different sections of the country and the seasonal variations are concerned. Attention is especially invited to figure 3 in that paper, showing the variations in solar radiation intensity with latitude, and also to figures 10 and 11, showing the average seasonal potential totals of radiation on a horizontal surface and the actual average amounts, based on the degree of cloudiness prevailing in different sections of the country.

GEOGRAPHIC DISTRIBUTION OF SUNSHINE.

Figure 3 shows the geographic distribution of sunshine for the year as a whole, expressed in percentage of the possible amount, the latter being essentially the same for all sections of the country, or an average of approximately 12 hours a day. This chart shows that the least amount is received along the north Pacific coast, where the sun shines on the average for the year during only about 40 per cent of the daylight hours, while in the Lake region, the central and northern portions of the Appalachian Mountain area, and the Northeast, the percentages are only slightly higher, 45 to 50. In the remaining districts east of the Mississippi River and in the northern States from the upper Great Lakes westward to the Rockies, the percentages range from 50 to 60, except that they are somewhat higher in the Southeast, especially in the Florida Peninsula. Between the Mississippi River and the Rocky Mountains the annual percentage is generally between 60 and 70, which is also true for the central Rocky Mountain region and northern Plateau States. The maximum amount of sunshine in the United States is received in the far Southwest, including extreme western Texas, New Mexico, Arizona, southern Nevada, and the adjoining portions of California. In the lower Colorado River Valley the sun shines on the average for the year nearly 90 per cent of the total number of hours from sunrise to sunset.

Figure 3 shows also the percentage of the possible amount of sunshine for each of the four seasons—winter, spring, summer, and fall. In winter the percentages range from less than 30 in the far Northwest and in portions of the Lake region, to more than 80 in the far Southwest; in spring, the variations for the same regions are from 40 to 50 in the former, to about 90 in the latter. In summer the extremes in percentages are 40 along the northern California coast to 95 in the Great Valley of California, while in fall they range from about 35 in limited areas in the Lake region to more than 90 in the lower Colorado River Valley. For the country as a whole the average annual percentage of the possible amount of sunshine is nearly 60 per cent, distributed through the seasons as follows: Winter, 48 per cent; spring, 60 per cent; summer, 68 per cent; fall, 60 per cent.

In some sections of the country the seasonal variations in the amount of sunshine, when expressed in percentage of the possible amount, are pronounced, while in others the distribution is quite uniform throughout the year. The interior districts, as a rule, have the more uniform values, while the Pacific Coast States and the region of the Great Lakes have wide variations.

Figure 7 presents data showing the seasonal variations for three selected stations where the distribution of sunshine is uniform throughout the year; these are for Yuma, Ariz., Denver, Colo., and Washington, D. C. This graph shows, also, similar data for three other stations where the seasonal variations are large—Fresno, Calif., Tacoma, Wash., and Binghamton, N. Y. The record for Yuma shows uniformly high percentages, and those for Denver and Washington uniform and moderately high values while the others show widely varying seasonal amounts.

Table 1 gives the average percentage of the possible amount of sunshine, by months and also for the year, for all regular reporting stations of the Weather Bureau equipped with automatic sunshine recorders. In the

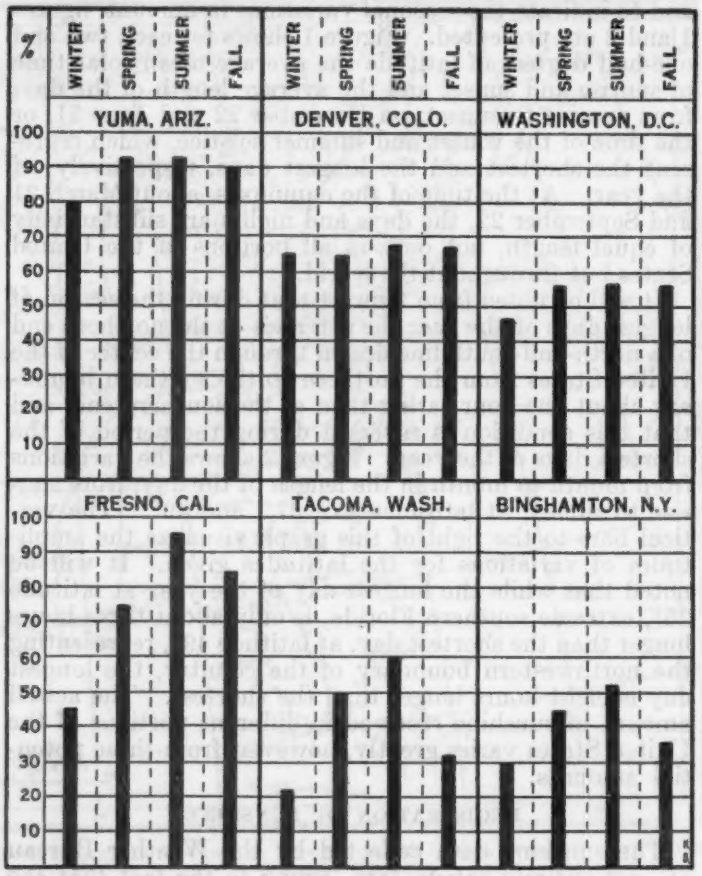


FIG. 7.—Seasonal variations in amount of sunshine.—Selected stations, showing uniform distribution in some localities and wide variations in others.

southeastern portions of the United States the spring months are the sunniest, while in much of the Ohio Valley and the Southwest June has a higher percentage of sunshine than any other month. July is the month of maximum in nearly half of the country, including all northern districts. The smallest percentage of the possible amount in much of the interior, and in the central and southern Pacific Coast districts and Southern Plateau States occurs in January, which is also the case in the Middle Atlantic States; in most other districts December is the cloudiest month.

SEASONAL VARIATIONS OF SUNSHINE.

Figures 4 and 5 show for the different sections of the United States, for each month of the year, the average number of hours of daily sunshine. These charts indicate the seasonal distribution of this important climatic

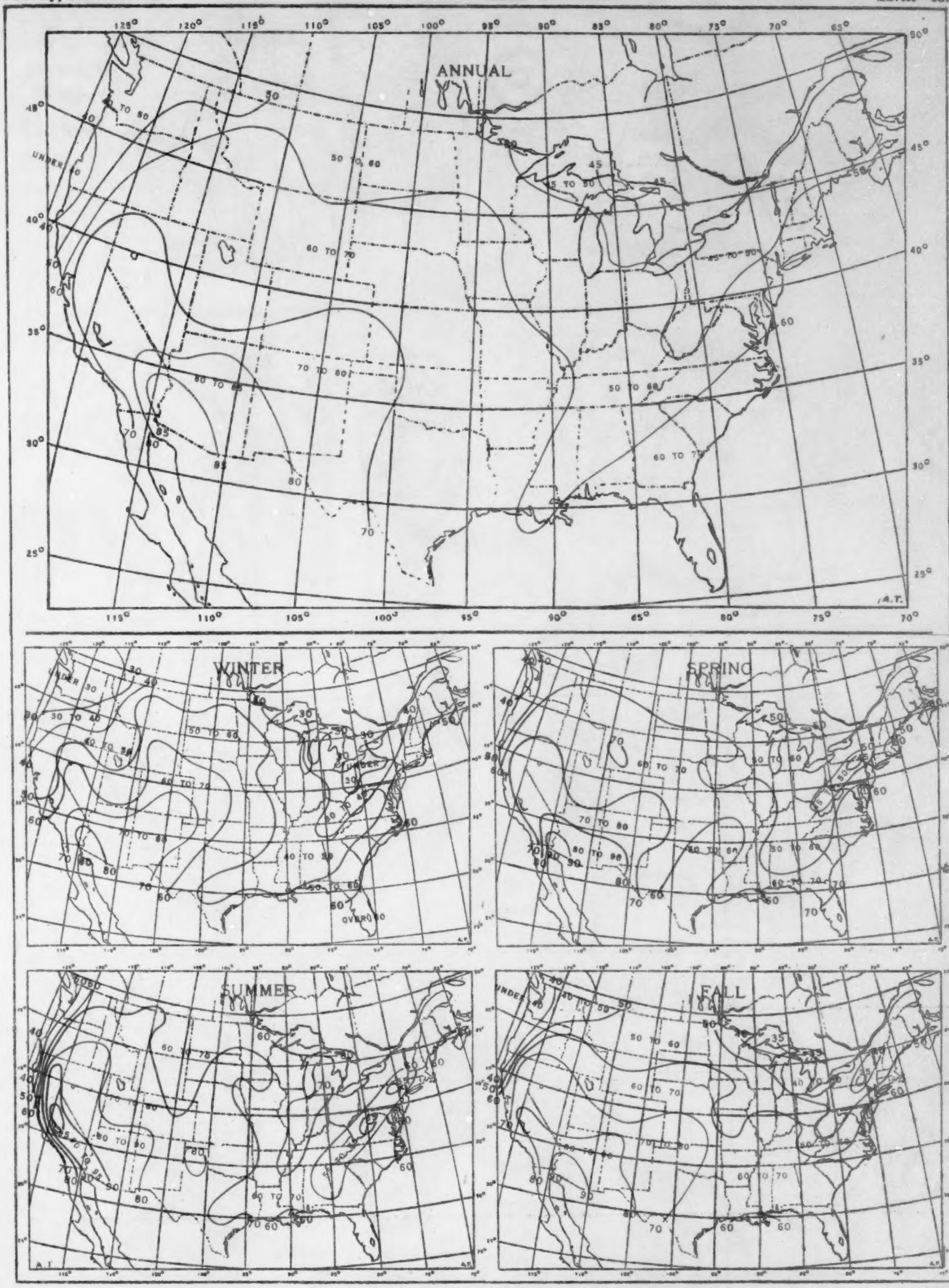


FIG. 3.—Percentage of possible amount of sunshine.

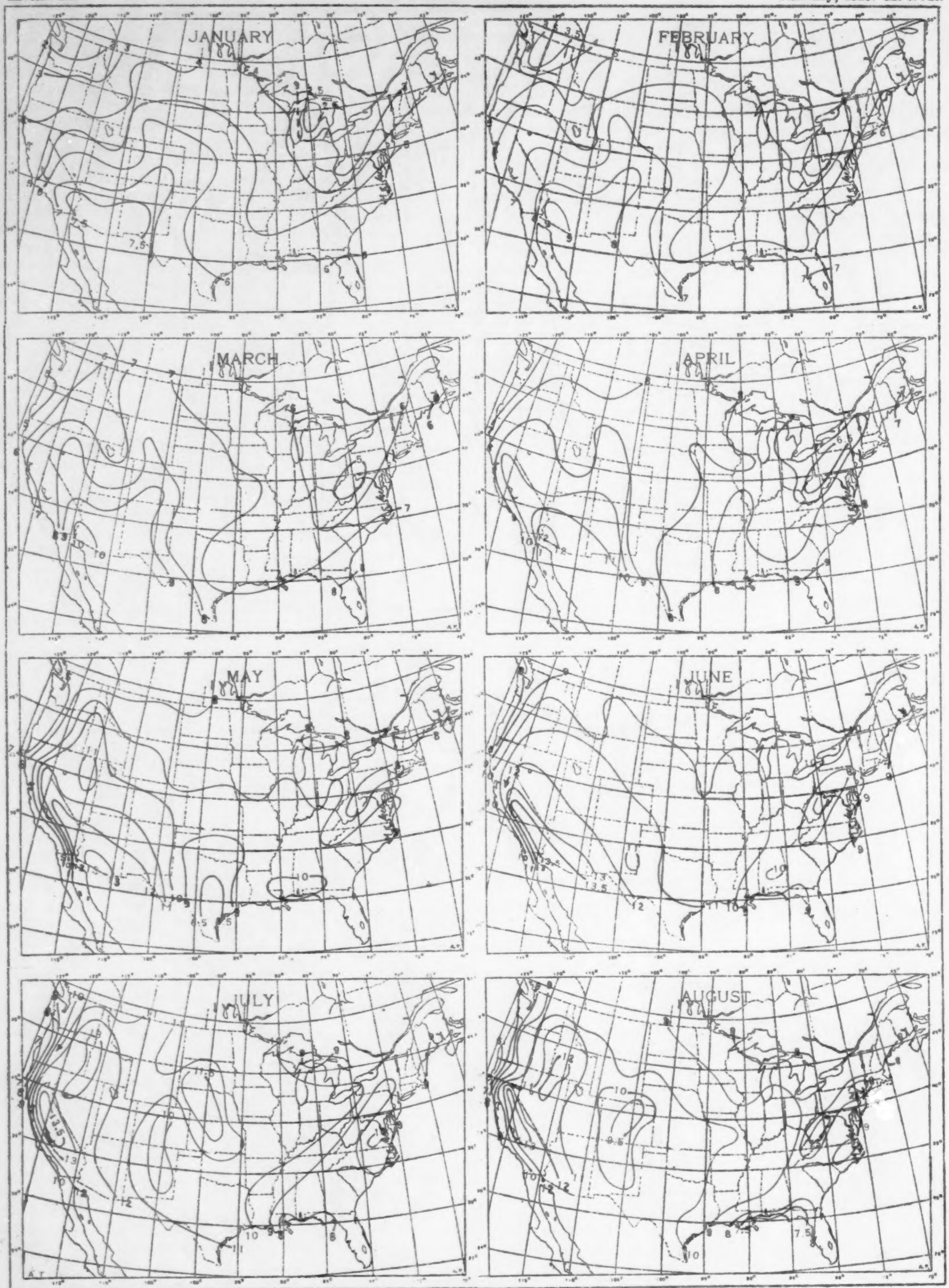
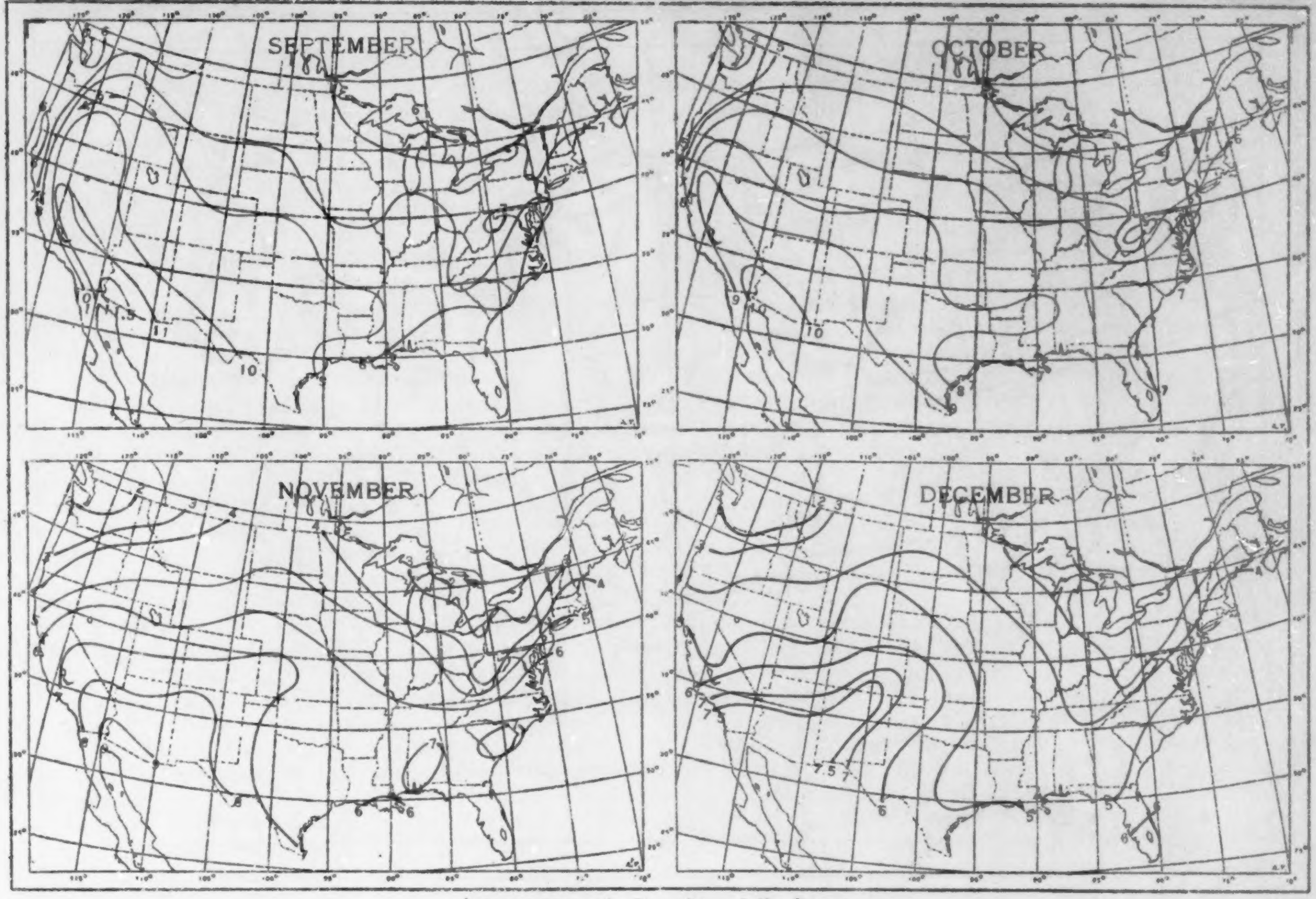
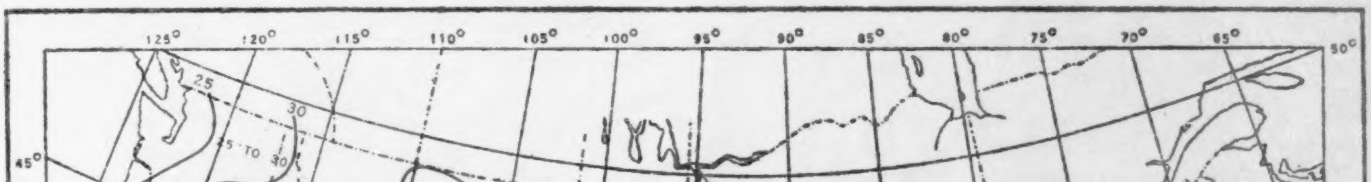


FIG. 4.—Average amount of sunshine daily, hours.



Average amount of sunshine daily, hours.



Percentage of days clear, annual.

FIG. 5.—Average amount of sunshine, daily; percentage of days clear, annual.

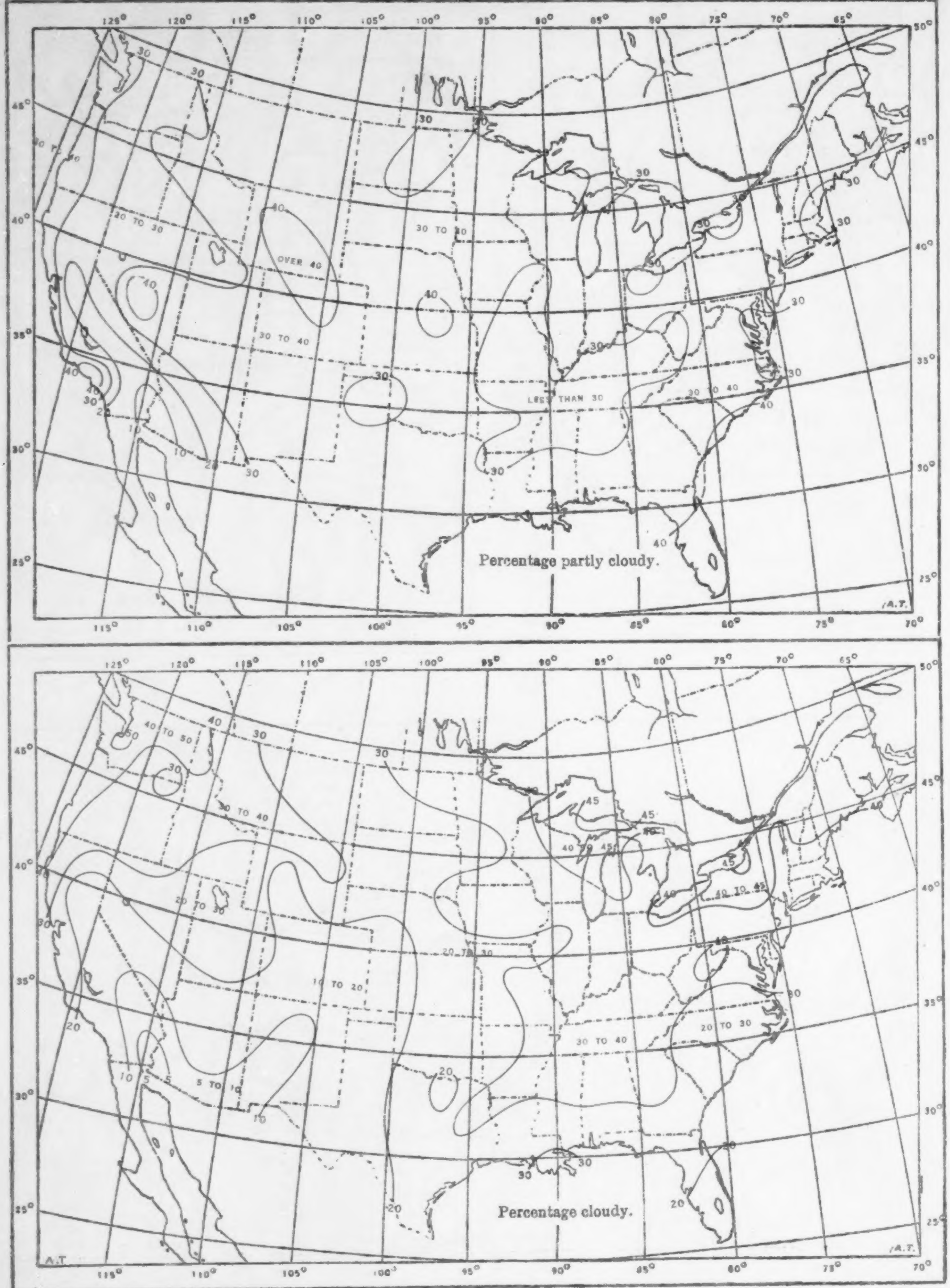


Fig. 6.—Percentage of days partly cloudy, and of days cloudy, annual.

factor. Owing to the fewer daylight hours, and also to the greater amount of cloudy weather in winter, the amount of sunshine is usually much less than in summer. Not only are there fewer actual sunshine hours in winter but the percentage of the possible amount is much less than in summer. This is due to the fact that in winter cyclonic action is more pronounced and several successive days of cloudy weather may be experienced in the passing of a storm, while in summer, cloudy weather and rainfall are usually of a more local character and there are fewer entirely overcast days. Cumulus clouds are characteristic of the summer season and consequently there are frequently successive short intervals of sunshine and cloudiness, particularly in the afternoon.

In the late fall and during most of the winter much cloudy weather prevails in the Great Lakes and in western Montana, northern Idaho, and in Washington, the average amount of sunshine in considerable areas being less than 3 hours daily and in some localities less than 2 hours. In extreme western Texas, most of New Mexico, and Arizona, and in southern California the winters, on the other hand, are sunny, these districts receiving on the average nearly 8 hours of sunshine daily in December and January, and 8 to 9 hours in February. In the Gulf States the amount of sunshine in winter ranges from an average of 4 to 5 hours in December to 6 or 7 hours in February, the maximum amount occurring in the Florida Peninsula.

With the advent of spring the amount of sunshine increases rapidly, especially in the more northern districts. In portions of the upper Lake region and the far Northwest, where in December and January the average sunshine is only about 2 hours daily, in April more than 7 hours is usually received. The maximum amount of sunshine during this season is received in the lower Colorado River Valley, where the average for the three spring months is about 12 hours a day, or 90 per cent of the possible amount. By May, there is an average of 9 to 10 hours of sunshine daily in the interior districts of the country.

The increase in the amount of sunshine from winter to summer in the northern portion of the United States is very pronounced. In most of the northern border States there are on the average in July about 6½ hours of daily sunshine in excess of that received in January. In the South the increases are not so pronounced, the daily July excess over January in the central and eastern Gulf States being only about 3 hours. East of the Rocky Mountains the geographic distribution of sunshine in summer is in general the reverse of that in winter, the northern districts receiving more than the southern. Much of the central and northern Great Plains usually receives in July from 40 to 50 per cent more sunshine than occurs along the central and east Gulf coast. The maximum summer amount for the country as a whole is experienced in the Great Valley of California and over the western portion of the Plateau region. The interior of California has almost continuous cloudless skies during the summer months, the average daily amount of sunshine in most of the Great Valley being nearly 14 hours, or about 95 per cent of that possible.

In autumn, especially during October and November, much cloudy weather is experienced in the region of the Great Lakes, the upper Ohio Valley, and the far Northwest, where in some places the average daily amount in November is less than 2 hours, but at the same time the daily averages in portions of the Southwest are in excess of 9 hours. In the fall, there is a uniform and rather marked increase in the amount of sunshine from the northeastern to the southwestern portions of the country. In interior districts the averages for this season are mostly 7 or 8 hours daily.

CHARACTER OF THE DAY.

The character of the day, as determined by the Weather Bureau, is divided into three groups. A day when the sky is three-tenths or less covered with clouds, on the average, is recorded as clear; from four-tenths to seven-tenths as partly cloudy; and eight-tenths or more as cloudy. The degree of cloudiness is determined by a number of eye observations throughout the day.

Figures 5 and 6 show for different sections of the country the average annual percentage of days clear, the average annual percentage partly cloudy, and the average annual percentage cloudy. It will be noted that the percentage of days clear for the year, as a whole, ranges from about 20 to 25 in the Lake region and the far Northwest to more than 85 in portions of the far Southwest; while the percentage of days cloudy range from 5 in the latter locality to more than 40 in the former.

While the extreme duration of periods of cloudy and clear weather that has been experienced is not climatically of great importance, it is of interest in a general discussion of sunshine and cloudiness. East of the Great Plains, the longest period of consecutive cloudy days that was experienced during the 20-year period from 1895 to 1914, ranged from 12 to 16, the number being about the same in all sections, except that it was only about 8 days in Florida, but 20 in the Lake region. In the western Great Plains, the southern Rocky Mountain, and much of the Plateau areas, the maximum number of successive cloudy days was about 10 in most localities, and ranged in the Pacific Coast States from 8 in southern California to 20 in western Washington. From the Mississippi Valley eastward the longest period of consecutive clear days experienced during these 20 years was generally about 15 days, except that in the Lake region it was about 10 and in Florida 20 days. In the Great Plains the longest clear period varied from 12 days in the central portion to 20 or more in both the northwestern and southern portions. In the western Plateau States and in the interior of California from 50 to 80 consecutive clear days were recorded during this period, but 10 was the limit along the north Pacific coast.

DIURNAL VARIATIONS IN SUNSHINE.

In general, the amount of sunshine is less during the early morning hours, with a secondary minimum in the late afternoon. The greatest amount occurs near midday.

Figure 8 shows the diurnal distribution of sunshine for several sections of the country, based on the average of five or six stations for each area designated, the areas covered being the Atlantic Coast States, the Gulf region, the interior, and the immediate Pacific coast districts. It will be noted from this graph that for the year, as a whole, the diurnal distribution of sunshine is quite uniform in all sections of the country. There are, however, wide seasonal variations in some localities, as is indicated by figure 9, which shows for the summer season—June to August, inclusive—the diurnal distribution of sunshine at San Diego and Fresno, Calif., Kansas City, Mo., and Tampa, Fla. At Fresno and Kansas City during the summer season sunshine is distributed rather uniformly throughout the day, but at San Diego the afternoons are much sunnier than the mornings,

while at Tampa these conditions are reversed. For the winter season in these localities the large variations do not appear.

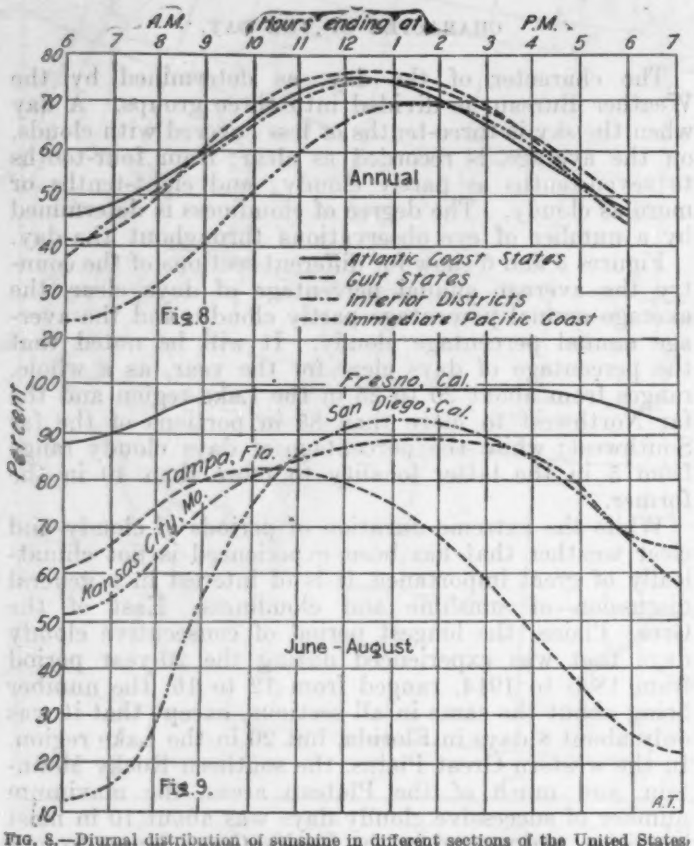


FIG. 8.—Diurnal distribution of sunshine in different sections of the United States: annual average. (Percentage of the possible amount.)

FIG. 9.—Diurnal distribution of sunshine, selected stations, for the summer season—June-August. (Percentage of the possible amount.)

The hour of maximum sunshine for the year, as a whole, varies for different sections of the country. In most localities the sunniest hour is from 12 to 1, although in some areas, including part of the upper Ohio Valley, Tennessee, and the east Gulf States, and the central Rocky Mountain and Plateau region, the maximum occurs from 11 to 12, while in much of the southern plains the sunniest hour is between 1 and 2. The earliest hour of maximum sunshine for the day, 10 to 11, is found in the Florida Peninsula and the southern Rocky Mountain districts. In the Gulf region the time of occurrence becomes progressively later from east to west. In the Florida Peninsula it is from 10 to 11; in the southern half of Georgia and of Alabama, 11 to 12; in the lower Mississippi Valley, 12 to 1; and in most of Texas, from 1 to 2. There is also a similar progression from the southern Rocky Mountains northward to the northern border districts.

TABLE 1.—*Percentage of possible amount of sunshine, monthly and annual (average for eight years, 1905–1912).*

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
ATLANTIC COAST.													
Eastport, Me.	37	49	48	50	46	50	55	55	50	47	34	37	46
Portland, Me.	55	64	64	60	57	64	67	64	59	61	49	54	60
Burlington, Vt.	33	47	51	51	51	62	67	61	51	43	22	20	47
Northfield, Vt.	38	53	58	54	50	60	67	62	54	48	31	33	51
Boston, Mass.	44	57	60	62	61	69	72	67	58	60	48	46	59
Block Island, R. I.	43	52	55	55	54	61	63	61	55	57	48	54	54
Providence, R. I.	43	56	55	59	55	63	63	61	53	58	50	49	55
Hartford, Conn.	44	56	55	56	52	57	59	52	47	51	38	42	51

TABLE 1.—*Percentage of possible amount of sunshine, monthly and annual (average for eight years, 1905–1912)*—Continued.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
ATLANTIC COAST—contd.													
New Haven, Conn.	47	59	59	59	57	64	66	61	57	62	53	52	58
Albany, N. Y.	38	47	51	51	49	56	59	54	47	48	34	34	47
Binghamton, N. Y.	29	39	44	44	46	53	53	47	43	40	23	22	40
New York, N. Y.	50	62	62	64	62	66	72	62	63	63	59	52	62
Harrisburg, Pa.	42	52	54	57	60	61	66	58	60	57	49	43	55
Philadelphia, Pa.	45	57	54	57	56	56	64	54	56	58	53	48	55
Atlantic City, N. J.	47	59	56	60	60	60	67	62	59	64	61	54	59
Baltimore, Md.	46	61	59	63	65	63	70	63	64	64	57	48	60
Washington, D. C.	39	54	52	56	62	56	62	52	53	61	55	48	54
Norfolk, Va.	53	58	60	60	63	57	61	59	60	64	64	55	60
Richmond, Va.	47	54	56	59	65	58	65	56	60	62	55	50	58
Lynchburg, Va.	45	53	56	59	67	62	68	61	62	63	56	47	58
Wytheville, Va.	43	49	51	55	62	59	59	55	60	58	56	40	54
Asheville, N. C.	48	52	55	58	61	57	56	53	60	60	61	45	56
Raleigh, N. C.	48	56	58	63	69	64	61	62	63	64	63	53	60
Wilmington, N. C.	59	62	66	68	68	68	66	62	63	68	72	61	65
Charleston, S. C.	61	62	69	70	69	69	63	67	68	68	70	56	66
Augusta, Ga.	53	58	64	64	69	67	62	68	65	69	65	52	63
Atlanta, Ga.	46	51	60	59	62	66	58	60	62	63	62	44	58
Macon, Ga.	49	50	60	57	61	63	56	60	58	64	65	46	57
Savannah, Ga.	56	58	67	65	66	67	58	62	57	62	67	52	61
GULF STATES.													
Jacksonville, Fla.	56	58	69	68	69	68	64	63	61	60	59	53	62
Tampa, Fla.	60	65	71	75	71	66	62	62	70	68	67	59	66
Mobile, Ala.	54	60	63	67	75	70	59	62	63	70	69	48	63
Birmingham, Ala.	46	51	56	56	53	63	57	61	64	64	64	42	56
Meridian, Miss.	43	52	58	56	64	64	56	64	69	65	60	42	58
Vicksburg, Miss.	49	53	61	61	70	71	62	69	74	70	62	45	62
New Orleans, La.	52	51	60	56	62	63	54	58	53	61	56	42	56
Little Rock, Ark.	48	55	57	57	64	60	68	70	74	71	61	49	62
Fort Smith, Ark.	49	56	55	56	66	70	72	71	73	67	62	50	62
Bentonville, Ark.	47	54	55	54	65	66	74	69	71	66	62	54	61
Oklahoma, Okla.	51	59	56	59	65	72	73	78	76	68	66	60	65
Houston, Tex.	61	57	57	54	70	73	66	74	72	68	61	42	63
Galveston, Tex.	60	59	63	63	71	83	74	73	71	71	61	51	67
San Antonio, Tex.	48	50	49	48	54	68	67	67	68	60	45	45	56
OHIO VALLEY AND TENNESSEE.													
Memphis, Tenn.	46	55	58	60	65	70	70	72	74	71	64	44	62
Chattanooga, Tenn.	37	45	50	52	61	60	56	59	60	65	56	39	53
Knoxville, Tenn.	40	50	54	56	63	60	59	53	64	65	60	40	55
Lexington, Ky.	30	42	46	56	64	62	61	63	61	58	46	31	52
Louisville, Ky.	38	48	51	54	61	70	66	65	65	62	56	40	56
Evansville, Ind.	54	50	56	60	82	78	81	77	79	67	52	51	66
Indianapolis, Ind.	35	47	49	52	57	67	63	66	65	60	56	42	55
Cincinnati, Ohio.	35	48	50	58	65	68	67	69	68	64	55	40	57
Columbus, Ohio.	36	48	49	55	65	67	68	68	66	61	50	27	55
Parkersburg, W. Va.	26	37	40	49	59	59	61	57	57	47	33	24	46
Elkins, W. Va.	30	39	42	47	58	54	56	54	56	49	41	30	46
Pittsburgh, Pa.	29	39	46	49	57	60	63	60	63	55	41	30	49
LAKE REGION.													
Canton, N. Y.	35	48	52	50	54	63	65	62	55	46	28	28	48
Rochester, N. Y.	29	40	48	53	59	66	73	68	63	55	31	25	51
Buffalo, N. Y.	23	40	48	49	55	61	67	62	57	49	30	25	46
Erie, Pa.	25	41	48	55	64	68	74	68	61	47	26	21	50
Cleveland, Ohio.	26	37	47	52	62	66	68	66	63	51	34	25	50
Toledo, Ohio.	32	41	49	51	62	65	69	68	63	54	40	31	52
Detroit, Mich.	31	41	48	49	58	61	70	66	61	53	35	27	50
Port Huron, Mich.	35	44	50	48	56	62	65	60	56	51	34	28	49
Grand Rapids, Mich.	27	38	48	51	57	63	67	66	56	51	32	24	48
Grand Haven, Mich.	24	34	52	54	59	68	71	68	60	52	33	24	50
Chicago, Ill.	37	47	55	58	65	73	71	69	65	61	52	42	58
Lansing, Mich.	45	52	64	66	72	76	76	68	59	55	31	32	58
Milwaukee, Wis.	44	51	55	54	55	66	69	65	63	56	48	44	56
Green Bay, Wis.	50	56	63	61	60	73	74	69	64	60	44	44	60
Escanaba, Wis.	44	46	55	50	52	67	65	58	55	47	31	34	50
Sault Ste. Marie, Mich.	28	42	51	49	50	63	62	53	47	36	17	19	43
Marquette, Mich.	38	42	52	54	52	62	62	54	48	39	24	25	46
UPPER MISSISSIPPI VALLEY.													
St. Paul, Minn.	50	62	62	63	59	66	75	70	62	58	48	44	60
La Crosse, Wis.	45	59	56	57	58	68	71	63	60	56	42	41	56
Madison, Wis.	43	51	52	51	54	65	62	65	59	52	42	40	55
Charles City, Iowa.	52	58	55	62	67	64	79	72	67	66	54	57	63
Dubuque, Iowa.	43	51	51	53	55	64	66	60	54	56	47	44	54
Des Moines, Iowa.	46	47	59	58	60	65	70	70	60	62	54	52	59
Peoria, Ill.	44	57	60	62	68	74	73	72	66	65	58	53	63
Springfield, Ill.	45	55	56	57	67	70	71	74	67	66	62	50	62
St. Louis, Mo.	42	51	56	57	67	64	66	66	64	60	58	44	58
MISSOURI VALLEY.													
Columbia, Mo.	48	57	58	57	67	66	69	72	61	64	58	55	61
Kansas City, Mo.	48	57	62	61	68	74	76	75	59	59	53	49	62
Topeka, Kans.	53	60	64	63	66	68	74	75	66	65	60	59	65
Dodge City, Kans.	64	64	62	70	70	75	77	75	77	73	71	70	70
Concordia, Kans.	60	64	76	73	70	77	81	80	72	72	75	63	72
North Platte, Nebr.	62	67	69	64	62	70	76	72	67	69	64	60	67
Omaha, Nebr.	47	57	54	58	59	64	68	67	59	61	51	51	58
Sioux City, Iowa.	44	56	59	55	57	63	69	72	64	64	59	48	59
Yankton, S. Dak.	48	62	60	60	57	60	66	71	67	62	65	58	60
Rapid City, S. Dak.	55	60	67	63	59	65	71	70	65	65	57	51	60
Huron, S. Dak.	53	66	60	64	64	68	74	74	65	62	54	50	63
Devils Lake, N. Dak.	55	59	59	62	52	58	68	62	60	54	48	45	57
Bismarck, N. Dak.	56	62	56	64	56	60	71	66	59	59	50	49	59
Williston, N. Dak.	45	60	55	58	54	61	69	65	59	51	43	40	55

TABLE 1.—*Percentage of possible amount of sunshine, monthly and annual (average for eight years, 1905–1912)*—Continued.

Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
MOUNTAIN REGION.													
Havre, Mont	51	58	66	66	60	70	76	71	62	58	43	42	60
Kalispell, Mont	27	37	53	55	48	54	70	63	54	52	27	18	46
Helena, Mont	50	61	70	66	57	62	77	70	60	61	48	48	61
Yellowstone Park, Wyo	38	52	62	66	51	63	75	73	63	62	52	49	59
Sheridan, Wyo	57	64	63	60	61	70	72	63	55	55	47	54	60
Lander, Wyo	66	74	76	73	68	73	76	78	70	68	55	62	70
Cheyenne, Wyo	62	67	64	64	57	68	66	69	63	65	61	64	64
Grand Junction, Colo	49	62	61	67	67	78	73	71	72	72	64	56	66
Durango, Colo	68	72	70	72	78	85	77	78	83	81	77	71	76
Denver, Colo	63	68	66	66	59	69	68	65	66	70	62	65	66
Pueblo, Colo	78	79	76	73	74	78	72	73	78	78	75	81	76
Amarillo, Tex	73	73	78	79	80	84	77	80	80	74	73	75	77
El Paso, Tex	74	79	80	86	91	89	74	75	84	85	76	72	80
Roswell, N. Mex	66	63	67	69	75	75	67	69	76	74	67	62	69
Santa Fe, N. Mex	71	69	69	73	78	82	65	68	80	80	72	74	73
Phoenix, Ariz	76	78	77	88	91	94	88	82	88	92	83	76	84
Yuma, Ariz	77	83	84	94	95	97	89	92	93	90	88	79	88
Tonopah, Nev	60	65	64	76	74	82	80	88	81	72	73	63	73
Modena, Utah	55	60	60	66	76	84	71	75	75	74	69	59	69
Salt Lake City, Utah	42	45	55	64	63	71	74	72	70	68	56	39	60
Winnemucca, Nev	49	58	67	75	76	83	90	92	84	77	64	50	72
Pocatello, Idaho	44	57	59	68	64	63	82	81	77	64	57	44	63
Boise, Idaho	36	49	60	71	70	76	88	88	77	70	50	36	64
Baker, Oreg	38	48	58	64	65	64	78	86	77	70	53	40	62
Walla Walla, Wash	26	38	62	70	69	75	87	81	69	62	37	22	58
Spokane, Wash	23	38	56	65	62	68	81	76	67	53	24	19	53
PACIFIC COAST.													
Seattle, Wash	33	35	48	52	50	52	64	57	48	37	25	22	44
Tacoma, Wash	21	29	46	55	50	53	65	61	47	30	17	14	41
North Head, Wash	28	42	49	52	48	46	49	50	50	45	30	30	43
Portland, Oreg	23	35	45	53	50	56	72	63	50	39	26	20	44
Eureka, Calif	28	34	43	51	48	45	37	37	40	42	33	34	39
Sacramento, Calif	39	58	61	78	79	86	96	96	89	81	63	45	73
San Francisco, Cal	40	50	54	68	69	68	61	59	64	71	56	54	60
Fresno, Calif	41	58	60	81	87	94	96	97	90	86	76	43	76
San Luis Obispo, Calif	46	58	54	66	66	70	74	76	74	74	67	62	66
Los Angeles, Calif	64	64	58	64	67	71	76	79	78	78	73	73	70
San Diego, Calif	63	62	58	65	60	61	65	72	75	75	73	73	67

THE SUN AS A SOURCE OF POWER.

The problem of harnessing the radiation of the sun, and converting it into power in such a manner as to render the results of commercial value, is not a new one. The attempt to use reflecting devices may be said to date from De Caux in 1615 and Buffon in 1747. But, aside from the mere general interest in the problem, its significance and importance are accentuated by the realization that the coal supply of the world is steadily being depleted. In addition, in tropical regions, where solar engines would give the greatest promise, coal is scarce, and a satisfactory device for obtaining power from radiation which would otherwise be used only in heating the earth's surface would be most welcome.

While it is interesting, it is not necessary, in this connection, to consider the opinions which have been advanced as to the reason for the maintenance of the sun's heat, but it is valuable to know the tremendous amount of energy which reaches the earth's surface daily. The *Scientific American* of October 7, 1916, says:

> The great glowing surface which the sun presents to us, even considered as a flat disk, has the enormous area of 585,750,000,000 square miles, each square foot of which emits the tremendous amount of about 12,500 horsepower. The average radiant energy received on the surface of the earth [in middle latitudes] at noon on a clear day is about 5,000 horsepower per acre.

Sir Oliver Lodge, who discussed this question before the Royal Society of Arts on December 10, 1919, expressed the opinion that the greatest good will be derived from the sun through the promotion of agriculture, inasmuch as the leaves of plants, unhampered by any efficiency limit imposed by the laws of thermodynamics, will use most efficiently the incident radiation. Dr. Horace Brown has shown, however, that vegetation is not the most efficient user of solar heat, for the amount of solar energy stored is less than 2 per cent of that which reaches the leaves. There appears to be a difference of opinion, also, in regard to the maximum possible thermal efficiency obtainable from such devices as have been suggested. These figures vary from 2 to more than 40 per cent, although they are based on many principles, theoretical and practical, and may not be of equal value. It can not be denied that the idea of a factory deriving its power from the solar radiation incident upon its roof is an attractive one, in spite of the general opinion of its impracticability.

Solar engines have been constructed which have given promise of considerable practical importance. Perhaps the most important of these is the one at Meadi, near Cairo, Egypt. This consists of five 205-foot boilers placed on edge and in the focus of five channel-shaped mirrors of parabolic cross section, giving a total area of 13,269 square feet. This plant gave as its best run for an hour 1,442 pounds of steam at a pressure of 15.8 pounds per square inch, which is equivalent to 63 horsepower per acre of land occupied by the plant. Tests have been made upon other engines of similar design but of different size. For example, it was found that the boilers were more productive when covered with glass. Meterological conditions also affect the steam production. Humidity, it was found, exerted so much influence that a decrease of 20 per cent gave an increased steam production of 30 per cent.[1]

Not all the theories for the utilization of the sun's energy are built around the idea of concentration of the sun's rays upon boilers, but others have been advanced in the more speculative field of electromagnetism. It is argued by Mr. A. A. Campbell Swinton, in a letter to *Nature*,[2] that by methods analogous to those which have produced such fruitful results in wireless communication, it may be possible to convert incident energy directly into usable electrical energy. The basis for his argument is that since the difference between the electromagnetic waves which reach us from the sun, and those emited from a wireless station, lies only in the wave length, it is possible to use the analogy of wireless development in predicting what may come from this line of experimentation. He predicts that the efficiency of this method, if it were devised, would be quite high, perhaps not less than 50 per cent. This idea seems quite attractive and perhaps more promising than the older idea of the heat engine.

Other interesting devices have been made of lesser practical importance. It is said[3] that in subtropical regions, where coal is scarce, such as Egypt, the Punjab, and the Karoo of South Africa, teakwood boxes, blackened within, fitted with glass tops, and properly insulated, have been found to register from 240° to 275° F. in the middle of the day, and, with the addition of an auxiliary mirror, to reach even 290°. The applications of such ovens are many, and there is no other expense than the initial construction. This is employed in those regions for cooking and baking as well as many other purposes.

In view of the declining natural resources of the world, the increasing studies in solar activity, and the application of electrical methods and devices, it is not idle to hope for an efficient and practical method of converting the sun's heat into usable commercial power.—*C. Le Roy Meisinger.*

[1] Swinton, A. A. Campbell: Power from the sun, *Nature*, Dec. 18, 1919, p. 392.
[2] *Scientific American Supplement*, Sept. 15, 1917, p. 176.
[3] Ackermann, A. S. E.: The utilization of solar energy, abstract in *Nature* (London), May 27, 1915, pp. 358-360, 3 figs.

ON OBSERVATIONS OF SOLAR AND SKY RADIATIONS AND THEIR IMPORTANCE TO CLIMATOLOGY AND BIOLOGY AND ALSO TO GEOPHYSICS AND ASTRONOMY.[1]

C. DORNO, Ph. D.

[Davos, Switzerland, Aug. 28, 1919.]

[Translated by W. W. Reed, Observer, Weather Bureau.]

SYNOPSIS.—Treated statically, solar and sky radiation measurements pertain to meteorology and climatology; while investigations into the variations of these two components and the causes thereof pertain to geophysics, astrophysics, and astronomy.

It is partly due to this division of interest in the problem, partly to lack of suitable measuring apparatus, and partly to lack of appreciation of the many practical applications of the results, that solar and sky radiation measurements have heretofore received so little attention.

From 1908 to 1910, inclusive, measurements were made at Davos, Switzerland, of the heat, the illumination, the chemical, and the ultra-violet intensity of solar radiation, and the means have been found to represent with sufficient exactness the radiation values for every hour of the day. Radiation values have also been coordinated with durations of sunshine and conditions of cloudiness.

The solar constant is one of the most important constants in nature, since upon it depends all organic life. For different climatic effects radiation, including the outgoing as well as the incoming, is among the most decisive elements. In the Alps spring sunshine is relatively rich in heat rays, autumn sunshine in ultra-violet rays. With average elevation of the sun in a cloudless sky the red solar light falling upon a horizontal surface is 14 times stronger than skylight, the visible rays 11 times stronger, the chemical rays 4 times stronger, and the ultra-violet only half as strong. It follows that photographic measurements of sunlight give no adequate indication of the solar climate of a place.

Measurements of the relative brightness of the sun and sky give a means of determining the atmospheric transmissibility. Observations of purely optical phenomena and especially optical disturbances have been found useful in the study of the atmosphere. The expression of the separate components of polarized light in absolute measures has afforded the possibility of explaining the variations of sky brightness, polarization, and color, dependent upon solar altitude and atmospheric transmissibility. It has been found that all the optical phenomena are closely related.—*H. H. K.*

INTRODUCTION.

The problem of solar and sky radiations can be considered from two entirely different view points—first, we may be content to record in a purely statistical way what amounts of radiation reach the earth's surface at the place of observation, and to determine the totals and distribution for the time of day and season of the year; then, we may inquire into the direct connection between solar and sky radiation and seek to investigate the variations which the two components show, and the origin and causes of the same.

The first part of the problem pertains to meteorology, especially "geographic meteorology", or climatology, and is useful in this science and through it in biology as a whole. The second part of the problem lies in the realm of geophysics, astrophysics, and astronomy.

Although almost all branches of natural science, including medicine, are concerned in the problem, and every one is individually and seriously interested—as is immediately evident and demonstrated right before our eyes by the restrictions relative to illumination and heating necessitated by the stress of war—still its solution is singularly delayed, and even to-day is not taken in hand as systematically as might be wished. Meteorology had to refuse to undertake the problem, although it concerns its chief and primal element, since, until lately, sufficiently simple, inexpensive and readily manipulated apparatus was lacking, and only a few observatories with personnel fully trained in scientific matters attempted the task; geophysics, astrophysics, and astronomy, occupied with the solution of more immediate and specifically interesting investigations, awaited the solution of the problem apparently belonging to the sister sciences; and until recently its importance appears to have been underestimated, and even at present, its value is not fully appreciated, despite the astonishing results in particular fields of solar investigation, Nevertheless, the results already realized are truly abundant enough to be referred to with pride; the way to decided results is paved; interest manifests itself in many directions—on the part of physiology and hygiene in an urgent call for the delivery of climatic radiation constants—and nowhere will such interest fail to appear when there is comprehension of the significance of the problem; in general, proper organization alone is necessary.

METHODS OF MEASUREMENT.

When, more than 14 years ago, I selected the high mountains as a place of residence I was soon convinced that radiation there presented one of the most important climatic factors; that up to that time its amount was more estimated than measured; and that the measurements based on summer expeditions by celebrated representatives of physics could give no sufficient conception of it; that the statements of literature, especially medical literature, were rather fragmentary and in part not free from error. Again, I was convinced that if the prerequisite conditions for accurate and adaptable continuous observations were compiled with both theoretically and instrumentally, the method of measurement, in order to be sufficient for the demands of practice, must begin with the well-known chief effects of radiation, namely, calorific, luminous, chemical, and bactericidal.

The wondrously exact spectro-analytic methods could not solve the problem since they were applied only to the most favorable, selected conditions; and from values relating to spectrum line width alone they did not permit simple conclusions as to the intensity of the entire solar spectrum nor of the larger portion of the spectrum as required in practice; then the numerous and widely employed photographic methods for the measurement of the illumination of the horizontal surface were not sufficient since, for the most part, they were entirely too inexact, and furthermore they took into consideration short-wave radiations exclusively, and these in rather inexactly defined portions of the spectrum.

The methods chosen for the accomplishment of the measurement which sufficed for the end to be attained were until 1907 employed at only a few places, never in connection with one another, and they had to be partially modified with application to conditions on high mountains. For the measurement of the heat intensity of the sunlight there was immediately available the Ångström compensation pyrheliometer, an instrument pronounced standard at the International Meteorological Directors' Conference at Innsbruck, soon supplemented by the rather readily manipulated and permanently highly trustworthy Michelson actinometer. For brightness measurements L. Weber's method, not connected with keenness of vision and thereby best meeting practical requirements, furnished a gratifyingly certain basis, and a broad one—since in addition to the equivalent value for the brightness it gives the intensity in red and green. Applied to regular observations only by the inventor at Breslau, later at Kiel for some decades, it fur-

[1] Presented at the one hundredth anniversary of the "Schweizerische Naturforschende Gesellschaft" at Lugano.

nished until then the only exact values with which hygienists might reckon and on which they could base rules for the illumination of interior spaces. For the determination of chemically active rays there served a photographic method, perfected by Konig and Weber and applied at a forest culture school to continuous observations—difficult, it is true—but one meeting strictly scientific demands. The ultra-violet radiation, in which the chief healing action was sought by medical science, was qualitatively investigated by means of the recording spectrograph made according to special instructions by Zeiss, and used chiefly for the determination of the extent of the ultra-violet spectrum and the change in its extent with the seasons of the year and the hours of the day, and quantitatively by means of the most exact instrument of this class, Elster and Geitel's zinc spherical photometer—which meanwhile has been far surpassed by the selfsame investigators with the use of cadmium and potassium cells.

After continuous observations with the use of this apparatus were carried through three years (1908–1910) and the results were combined in tables, which, in addition to giving—as customary—the air masses traversed according to elevation of the sun and hour of the day and the "normal values," showed the changes of these normal values under the influence of different degrees of cloudiness, brightness, and elevation of the sun, then the physician, for whom the work was first contemplated, was placed in the position to read in exact figures the radiation values for every hour of the day; also equally favored were the meteorologist, the climatologist, and the biologist. Haphazard observations carried on in later years have shown that normal values were derived with sufficient exactness by the 3-year observation series. The value of this working method lies, among other things, in the fact that measurements require only a single series of observations, which, to be sure, must be sufficiently long for an exact comprehension of the normal values, and in the fact that the deduction of definite values is referred once for all to the observation of duration of sunshine and conditions of cloudiness, which nowadays is everywhere furnished by meteorological services.

Naturally, effort is to be made to acquire recording instruments. There is a common misconception as to the difficulty of accurately manufacturing and giving practical attention to such instruments used for the simpler elements of air pressure, humidity, and temperature; for radiation measurements these difficulties are far greater, since isolation from immediate surroundings is to be obtained only with very costly and extensive auxiliary devices.

GREAT DIFFERENCES IN RADIATION FROM TIME TO TIME AND PLACE TO PLACE.

In the adaptation to practical use the greatest consideration should be given to the contents of the book, Essay on the Light and Air of High Mountains (Viewegs, 1911), which, in addition to radiation values, treats of atmospheric electricity, and radioactivity; besides, consideration should be given to comparison of results of measurements with respect to characteristics at other places in the same radiation region and also at those in other regions. Such comparison may show that the differences in absolute amount of radiation and in distribution through the day and the year, from place to place, are far greater and therefore more characteristic than those of the other meteorological elements; whence it might be concluded that for different climatic effects radiation is among the most decisive elements. In this there is to be considered not only the difference in the amount of insolation, but also that in outward radiation, since not only at night, but also by day there occurs in high mountains and prevalently everywhere in the polar and temperate regions a radiation from the earth to the sky except in the immediate vicinity of the sun.

A few numerical examples may be interesting. At noon in midwinter Davos has 6 times the brightness of Kiel; in midsummer, 1.8; and for the yearly mean, 2.5 times the amount of the latter. The high mountain has thus a very much brighter illumination than the plain and very much more favorable distribution of this brightness through the year, since the winter brightness exceeds that of the plain very much more than does the summer brightness. The amplitude of the monthly means amounts to 3.0 at Davos, 7.9 at Kiel; the amplitude of the absolute maxima and minima amounts to 32.3 at the former, 219.0 at the latter. At Davos with snow covering in winter the mean illumination of the vertical surface at angles of 0°, 90°, 135°, and 180° to the sun direction (*Vorderlicht*), which thus includes the reflection of the ground, equals the illumination of the horizontal surface (*Oberlicht*), while in summer it totals barely three-fourths of the same. So far as comparisons are at present possible the effect of snow reflections exceeds those of the beach and the sea surface. In winter the sun sheds on Davos three times the amount of heat that Potsdam receives; in summer the differences are moderate. Also in this connection there is evident the especially favorable distribution of the amounts of radiation through the year in the high mountains. Of all places from which data are available Davos has by far the greatest heat total, although as a result of valley location there is an average daily loss of three hours' sunshine; only the more southerly situated Washington with its entirely unobstructed horizon reports a slightly higher value.

The solar radiation is by no means always similarly composed; the low sun is much richer in long-waved radiations (much redder) than the high sun, as every one knows from experience. Also with the same elevation of the sun there exists a pronounced yearly march. The spring sunlight is—at least on the Alpine heights—much richer in heat rays, that of autumn much richer in the ultra-violet ones. The difference between sunlight and shadow light increases in marked degree with elevation of the sun and still more so with the color of the light, since the sky, as appearance teaches, is much richer in short-wave (blue) light than the sun with its long-wave rays (infra-red, red, and yellow). With middle sun elevations and cloudless sky the red light of the sun falling on the horizontal surface is found to be 14 times stronger than that from the sky, while its brightness is only 11 times stronger, its chemical rays only 4.4 times, its pure ultra-violet (bactericidal) rays even less strong than those of the sky (only about half so powerful).

From this it follows that a photographic method, were it even, as the Weber-Konig, exact to about 2½ per cent and not, as the widely used Weisner, to only 20 per cent. can never sufficiently characterize the light climate of a place. By a 9-month parallel series for the illumination of the horizontal surface the author has demonstrated that the light totals of the direct rays, with high elevation of the sun, are measured 2.0 times as great photographically as photometrically, those of diffuse sky light at low elevation of the sun about 4.5, at high elevation, 7; those of the total light at low sun elevation 1.75, at high elevation, 2.75 times as great, provided the minima are

taken equal; and the ratio of sunlight to shadow light will be found 3.4 times higher photographically than photometrically in the yearly mean, varying between 5.0 in winter and 2.0 in summer. It is seen that there is a question of a difference of hundreds of per cent. Those who are able to appreciate such figures will read attentively because of these few examples, and will immediately understand the importance of comparative measurements at different places.

PHYSIOLOGICAL IMPORTANCE.

"Suggestions for the Systematic Study of Light Climate and Air Climate of Places of Interest to the German Physician," written at the suggestion of Prof. Dietrich, of the Ministry of the Interior, the intellectual leader of the Central Office of Balneology, found full recognition, and Prof. Hellmann, who followed similar plans, supplemented the work in ample manner. If complete success has not been attained it is due to the sorrowful events of the day.

However, some stations parallel to Davos are established and some of these have been in operation for a long time, as for example, Potsdam and Kolberg, whose data should soon be given publicity. At Oberhof preparation was made for continuous observations; in the North Sea islands work was carried on by doctors from Kiel and physiologists from Berlin. At Essen and thence out into the Teutobergerwald stations are located, likewise on the Feldberg in the Taunus; St. Blasien has begun observations. In Allgau careful solar intensity observations have been made for several years. The aeronautical observatory at Lindenberg has taken up the problem with characteristic energy; P. Schreiber reported a few values from the Saxon Weather Service (Wahnsdorf). Then too there must be permanent and temporary stations that have not come to the attention of the author directly or indirectly. Interest is aroused outside of Germany; in Switzerland, crossed by the Alpine crest dividing weather and climate and therefore specially suited to comparative measurements, the first steps toward the inauguration of such have been taken; in the Baltic Provinces of Russia such measurements were nearing achievement shortly before the war; conditions were similar in Holland; while in Austria, in many ways leading in meteorological science, there is unfortunately still the belief that success may be had with the Weisner method. If last mention is made of the pioneer stations in heat radiation measurements, Upsala, Stockholm, Moscow, and Warsaw and of the standard solar intensity measurements in the United States, it is because they have hitherto been occupied almost exclusively with the total energy, and not with that of the separate portions of the spectrum, or have not turned knowledge of such to account climatologically when it has been obtained in solar investigation.

The requirement question was briefly touched upon heretofore. Just a short time ago one of the foremost hygienists of Germany complained to me that he must consider the values of brightness given by Weber for Kiel as by no means representing mean conditions in Germany. How shall the physiologist or the biologist arrive at certain results in his research work when he does not know the intensity and spectral composition of the sunlight and daylight at his disposal, and may err by hundreds of per cent in its estimation? In laboratory experiments he calculates with the accuracy of a few per cent, while on the other hand the meteorological factors which combine in nature are practically missing. The same holds for therapeutic light baths. Investigation on one hand with artificial light, with attendant influences unavoidably more or less harmful, or at least by no means curative, and on the other with sun and air baths must supplement each other; and there is certainly still difficult work to perform before no doubt shall prevail as to the utility of the different factors, and opportunity shall be given to use fully this natural and truly not ineffective source of healing. In order to get a striking example of the question of requirement let medical literature on the effect of light on the blood be read; even with the most serious physicians there enters not rarely at the conclusion of all reflections the question of a still entirely unknown, mysterious content of solar radiation, which idea persists, and a positive solution of this exceedingly important question can hardly be expected until the physician is placed in a position to investigate the effects of different spectral portions on the blood as compared with unchanged natural conditions.

If the desired end is to be attained, one thing is necessary; perfected organization, which should give attention to the following: Accurately adjusted, uniform apparatus and a program of observation and elaboration; synchronous observations, since optical disturbances are not rare; the employment of absolute and fixed measures, adaptable to the ordinary artificial sources of light; an industrious observing personnel, well educated in physics.

One of the established meteorological or geophysical observatories will, in view of the important and urgent nature of the problem, be found disposed to carry it into execution, and the opportunity will arise since international arrangements among all civilized countries will again be possible.

BEARING ON GEOPHYSICS AND ASTRONOMY.

Let us now turn to the advances and interests of geophysics and astronomy. These are great and, thanks to Abbot, are celebrating a triumph in the United States. May the demands which such extraordinary popularity makes of the scientific investigator not interfere with prosecution of his work!

The procedure in the determination of the solar constant and of the extraterrestrial solar spectrum, on which many other investigations hinge, which was established by Langley and largely and accurately developed by Abbot and his coworkers, Fowle and Aldrich, with the aid of munificent endowments and through indefatigable zeal, extraordinary intellectual grasp, experimental ingenuity, and technical skill, consists essentially in the following attainment. It is possible within only 11 minutes to register photographically the energy curve of the entire solar spectum from extreme infra-red to extreme ultra-violet so exactly that, for example, even the delicate nickel line lying between the two D lines of sodium comes to view, and simultaneous determinations of the heat intensity of solar radiation can be proceeded with through the employment of a pyrheliometer excelling the Ångström instrument and protected with extreme care from the radiating influences of the surroundings.

Through the combination of these two methods of measurement there is obtained both the distribution of energy and the energy of any spectrum portion in absolute terms. If several such curves at different sun elevations and with unchanged atmospheric conditions are considered, then the total energy of the extraterres-

trial spectrum and its distribution may be inferred by extrapolation. Those who wish to be informed in detail on the method of measurement and generally on the whole extensive problem of sun and sky radiations may refer to volume 63 of "Die Wissenschaften" (Vieweg). In it will be found the essential facts as to the composition of the atmosphere up its highest elevations (estimated at some 500 km.) and the laws according to which it acts through dispersion and absorption on the solar radiation traversing it, and also the results to which these processes lead; namely, polarization of light and color of the sky; also there will be found the optical influences of water vapor and cosmic and telluric dust. The statements made in that paper must be considered as preliminary to the full understanding of the following geophysical discussions.

THE SOLAR CONSTANT.

Of the results obtained, chiefly on Mount Wilson in California (1730 m.) and to be credited principally to Abbot, a few may be given here. These have been checked and supplemented by extremely careful and varied parallel observations at numerous places on the earth, often by German hand and with measurement methods and apparatus originating in the German mind.

The solar constant, that is, the intensity of solar radiation on its entrance into the earth's atmosphere, or the energy supplied at that point to a square centimeter in the path of the radiation in one minute, amounts to 1.925 gr. cal./min. cm.[2] This is a mean value from hundreds of measurements; in reality the values vary a few per cent with dependence on solar activity; an increase in the value of the solar constant accompanying an increase in sunspots. In rough approximation an increase in sunspot number of about 100 corresponds to an increase of 0.07 calorie in the solar constant. According to the latest investigations solar radiation appears to stand in more certain relation to change in distribution of brilliancy over the entire disk of the sun than to sunspot number. The value of the solar constant decreases with decreasing contrast in brilliancy from the sun's center to limb. According to this the radiation oscillations resulting from a rupture of separate places in the sun's envelope are slighter than those from a change affecting the entire solar sphere. Periodic oscillations within the duration of a day are believed to have been observed occasionally, but they are not to be considered as established; such changes of hours duration, which are assumed in analogy to the periodic brilliancy of fixed stars of the sun's age, in so far as they exist, must lie below 1 per cent.

The temperature of the photosphere is calculated from the solar constant and from the position of the maximum of energy in the solar spectrum according to Stefan's and Wien's laws of radiation, in apparently good agreement with one another, at about 6,000° C., assuming that the sun radiates as a dark body. From the deviations of the energy curve of the extraterrestrial solar spectrum as compared with that of the dark body the temperature must be estimated higher, between 6,000° and 7,000° C. In the paper mentioned there are to be found the most important facts relative to the curves of the extraterrestrial and of the terrestrial solar spectrum, their oscillations, the causes of premature diminution on the short-wave and long-wave ends, the origin of absorption bands, and the conclusions to which the same have led. However, this can not be entered upon at this place.

As is immediately obvious, the solar constant is one of the most important constants in nature, since on it depends all organic life. Exact knowledge concerning it is therefore of the greatest importance, and for this reason there has been no lack of very sharp criticism of the Langley-Abbot method. So far as these relate to change of atmospheric transmission during the time of observation, to too feeble resolvent power of the lens, to defect in apparatus, and to methods of calculation, one should not attach to them too much value. But on the other hand lies the fact that as to radiation that does not reach the ground nothing can be ascertained by process of extrapolation. Usually the errors entering in this way are estimated at only a few per cent, and the value of 5.85 at the limit of the photosphere as derived by Bigelow by nonadiabatic thermo-dynamics, allowing for gravitation, and of 3.98 at the limit of the earth's atmosphere must stand, on the whole, disproven by Very's and Abbot's replies. Bigelow's four fundamental formulas advanced in quite recent time and the conclusions which he draws from them relative to pyrheliometry require further proof.

SKY RADIATION.

What valuable application a better guaranteed value of the solar constant can find in geophysics has been demonstrated by Abbot and Emden. The former, having recourse to supplementary heat radiation measurements of the cloudless sky, of the earth, and of the clouds (distinguished as higher and lower) derived 0.37 as the energy albedo of the earth as a planet. From this value, the ground temperature, and the solar constant Emden was able to calculate the decrease in radiation by the atmosphere with height, and the retention of heat which the different zones of the earth experience in the different seasons through the sheltering mantle of the atmosphere. According to this, the radiation from the sky exceeds in winter everywhere except at the equator, and in middle Europe in January the atmosphere radiates two or three times more heat to the earth than is radiated by the sun, since, as a result of the general circulation, at this season air masses laden with heat and capable of radiation are carried from equatorial into higher latitudes. In these calculations Emden treats the short-wave solar radiations and the long-wave atmospheric radiations separately and assumes both kinds as gray with different absorption coefficients. His values agree very well with values of outward radiation ascertained by measurement. The wide employment of the last class of measurements is to be encouraged, and here I may direct attention to the small instrument, "tulipan," devised by Ångström. It is based on the principle of compensation for the cooling of a black surface radiating to the sky by the overdistillation of ether vapor. Although liable to error, the instrument is, according to may experience, still adaptable and furnishes for the outward radiation amount an integral value for the entire night, which serves as a valuable supplement in judging of conditions during the night. It may be noted here that Fowle by laboratory experiments on a grand scale, with tubes 128 and 246 meters long, has arrived at a spectrographic method for determining the water vapor content of the entire atmosphere up to its highest limit, which appears to leave nothing to be desired as to precision, and which has stood successfully many tests in connection with records from balloons

With Abbot's above-mentioned albedo value for the cloudless sky there stands in correct relationship the parallel value, which the author has ascertained by extensive measurement as to the light economy of the atmosphere.

OPTICAL PHENOMENA.

The purely optical phenomena have proven especially productive of results in the investigation of the atmosphere, and thereby in geophysics. First from the consideration of auroral and meteoric phenomena connectedly they have essentially confirmed the computations as to the composition of the atmosphere up to an elevation of 500 km. which were begun by Humphreys and Hann and systematically developed by A. Wegener; in which connection optical disturbance, in addition to twilight phenomena, have contributed abundantly. So far as the relatively brief time of the observations permits judgment these last again make it very probable that a continuous relation exists between them and solar activity, of which one must make a threefold differentiation—(1) an indirect relation, since at the time of solar activity volcanic activity on the earth usually increases, and this changes the permeability of the atmosphere in well understood range of time and space; (2) a direct relation, parallel to the 11⅓-year solar period; (3) an enduring relation, corresponding to each separate evolution of solar energy, originating suddenly, continuing relatively briefly, and by no means affecting all places on the earth equally, since the incidence of corpuscular radiation from the sun will hardly take place in like manner and with equal force at all places on the day side of the earth, much less then on the night side, and the electrically laden particles will follow the earth's field of force.

With the superposition of these classes of disturbances explanation becomes difficult; purely meteorological influences of the lowest atmospheric strata can often prevent the possibility of observation, and, what is of more consequence, can give opportunity for misinterpretation, for example, through the occurrence of entirely uniform, thin haze, and through the influence of the seasons, which is an unexpectedly great one, judging from the author's extensive investigations at an elevation of 1,600 meters. The preliminary condition for correct interpretation is a very accurate study of the unclouded sky, and only places in specially favorable location will permit the prosecution of such study with sufficient accuracy, probably only those situated more than 1,000 meters above sea level, on extended plateau, and at a distance from the sea.

From vocation the author had the good fortune to be located at such a place, and he has attempted—he will acknowledge in ignorance of the extent of the problem, otherwise he had not ventured—to enter upon such a study of normal values, and to give through it a basis for trustworthy comparison with the phenomena of disturbance periods. Furthermore, he was fortunate in that tests were once possible at the time of conspicuous volcanic phenomena after the eruption of Katmai (1912–1914), and afterwards at the time of briskly reviving solar activity; so that the fundamentally different optical disturbance phenomena, coming at one time from within and at the other from without, could be evaluated quantitatively and qualitatively. There have been established normal values of absolute brightness, of amount of polarization, and of the position of the polarization plane for each point of the sky at all elevations of the sun and at all seasons, and indeed, except in equivalent values of brightness, also (to greater or less extent) in numerous spectral colors as far as into the pure ultra-violet. At the same time the albedo of the ground with different coverings and the influence of the natural horizon had to be ascertained. Control measurements of the illumination of the horizontal surface by sunlight and skylight have demonstrated the correctness of the results. Calculation in regard to the light economy of the atmosphere, which were made possible by determinations of the intensity of solar radiation carried on at the same time, have led to an intelligent course of reasoning. The expression of the separate components of polarized light in absolute measure afforded the possibility of a comprehensive and coherent explanation of all the variations of brightness, polarization, and color arising from dependence on elevation of the sun and atmospheric transmissibility, and the opportunity of investigation as to the extent to which the dispersion of light in the high mountains follows the laws contained in the prevailing theories. The results are collected in the papers of the Prussian Meteorological Institute, Vol. V, No. 295 (1917), and Vol. VI, No. 303 (1919).

It has been found that no one of the numerous optical phenomena is without close relation to the others; in agreement all have led to the same explanation as to the location and class of the disturbances, and demonstrate that by such observations there is obtained accurate information as to the character and extent of optical disturbances; some examples might be advanced showing that, under given conditions, by combination of several optical effects at different points of the sky pseudonormal values are found, so that none of the methods of investigation was useless.

The comparison made possible by numerous parallel observations permits decision as to the accuracy and advantages of the different methods, by which—with ultimate idea of wider extension of such investigations—is to be understood reasonable cost of apparatus, ease with which it may be manipulated, and the least possible consumption of time in the observation itself and in the resulting work of calculation and tabulation. Besides these results, which somewhat pave the way for further activity in the field of atmospheric optics, others may be mentioned.

The chief argument as regards brightness, polarization, and color, and even more for their distribution over the sky is the elevation of the sun. In addition—with the sun's elevation the same—the season exerts an unexpectedly great influence. Without reference to this, entirely false conclusions are reached in the comparison of amounts relating to equal elevation of the sun. This discovery comes to astronomy probably rather opportunely at the moment when there is deliberation as to whether or not even the observed oscillations of the height of the pole find their explanation to be in part a consequence of refraction changes due to meteorological changes.

Summer is by far the most unfavorable season for observations in atmospheric optics. Only those who have made regular observations for many years on the stars in high mountain regions are in a position to appreciate the full value of the winter and the spring sky, A simple evidence is that in winter Venus is not infrequently plainly visible to the naked eye at midday, so pure and therefore so little light scattering (dark) is the winter sky. Also in California this advantage of the winter sky probably exists; Abbot has not been able, however, to avail himself of it.

The high mountain air disperses radiation very largely by molecular diffraction according to Rayleigh's law. The amounts of dispersion through diffraction, reflection, and refraction by water droplets, ice crystals, or by dust particles is to be estimated at 10 per cent for high elevations of the sun, at 30 per cent for low elevations, and it extends in the main only to about 20° solar distance with high sun, to 40° with low sun. But in the application of Rayleigh's law not only is the stratum thickness to be taken into account on approach to the horizon, but also in large measure the extinction of solar radiation on its path from the sun to the dispersing particles and

from these to the observer by manifold diffusion on the multiform intervening paths, in which the extinction coefficient is not uniform as a result of change of color proceeding with dispersion of the rays, but constantly varying and always smaller for the first diffusion than for the manifold diffusion.

Position, extent in height, and composition of the disturbance strata are, as is to be expected, determinable within certain limits by the methods of observation employed, in which connection in order to prevent deception by purely local or meteorological effects it is truly more than desirable that comparisons between observations from very favorably situated stations rather distant one from another be made possible.

In the year 1912 the disturbance stratum of the atmosphere which was produced after the eruption of Katmai extended from the ground to high elevations. After the fading away of the first coarse masses, which took place in the period from June to October, 1912, it was composed of relatively coarse foreign substances generally exceeding the size of the cloud elements; with some oscillations it subsided very gradually until the second half of the year 1914. The last fading of coarser particles took place in February, 1914, at which time similar optical effects (although differently explained, it is true) were observed in the United States and at Davos. From reports available to date it is to be concluded that the fading away took place in a manner similar to that observed at Davos in the whole territory which the disturbance had embraced; that is, over the entire northern hemisphere from near the poles to the "Horse Latitudes." This argues against the existence of a brisk circulation exchange in the atmosphere over those latitudes; and there is indication in exactly that direction by some optical phenomena, which are most easily explained by the greater tenuity of the atmosphere in the warm season, for example the yearly march in different spectral portions of solar radiation, increasing with decreasing wave length and manifesting itself very significantly in the ultra-violet in marked excess of the autumn value over the spring value in the intensity and extent of the same.

During the solar disturbances occurring fitfully in 1915 and in the first half of 1916, accompanied by entirely characteristic phenomena, very readily observed in the "telluric solar corona," and quickly fading, and also during those in the second half of 1916, and at the beginning of 1917, occurring intensely and continuously and then gradually subsiding during 1917 and 1918, the disturbance stratum never reached the earth, but floated at varying height and always at great elevation, and was of massive thickness, consisting of particles of the minuest mass, estimated at 0.75 μ and from 10 to 40 times as large, the maxima not exceeding the size of the cloud elements.

How the proofs of these explanations were produced must be gotten by reference to the original paper. The change in absolute brightness of the different components manifests itself most abundantly, although it is certainly most difficult to be observed and requires simultaneous measurement of polarization and brightness in absolute terms.

OBSERVATION OF THE PHENOMENA OF ATMOSPHERIC OPTICS.

With reference to the wider distribution of the observation of the phenomena of atmospheric optics, mention may be made as to the sequence in methods of observation that I can recommend from means at disposal and my experiences.

1. *Purely visual methods.*—Scrutiny of the sky for the "telluric solar corona" (observable only at heights above 800 meters, visible at lower elevations as Bishop's ring only at the time of coarser disturbances); maintenance of watch for colored twilight phenomena, especially the primary and secondary purple light, for which Gruner has given excellent instructions, and for the occurrence of extremely high cirri at and shortly after sunset, and for luminous clouds at night. Also in the zodiacal light the intense disturbance phenomena should be plainly noticeable, and the phenomena of meteors and auroras should occur differently in intensity, extent, and color, according as they take place in a pure or in a dust-filled atmosphere.

2. *Instrumental methods.*—The observation of the neutral points during twilight, for which Busch and Jensen have given excellent instructions in their well-known Facts and Theories of Atmospheric Polarization. These are very profitably supplemented by those of the neutral lines (the isoclinics of 45° between polarization and vertical planes) during the day and twilight. As the author has demonstrated, they make possible a very accurate decision as to the momentary degree of transmissibility of the atmosphere in all sky directions.

The observation of the diminution in brightness from the sun to the adjacent sky, which will be entered upon in detail later.

The observation of the amount of polarization at the point of maximum, and especially at the zenith during twilight.

3. *Absolute measurements of brightness.*—Of all the methods this makes the greatest demand upon the observer and requires very painstaking prosecution in determination of constants.

In my observation of the diminution of brightness from the sun to the adjacent sky, the procedure was that the sunlight was passed centrally through a fixed optical system constructed of quartz, and there were determined, photometrically and photoelectrically in numerous specrum portions extending into the ultra-violet, the radiation effects which a solar field and a sky field of a tenth of a degree diameter each released respectively. By readings of one-fourth to one-half minute, accurate to the second, in the vicinity of the sun's limb and of 1 minute at somewhat greater distance and the conversion of the time into angular distance, considering the declination of the sun, the curves of diminution of brightness could be determined rather exactly. These curves depend in greatest measure on the elevation of the sun, then on the season and on the general degree of purity of the atmosphere; for these also it is first necessary to fix normal values before it is known how to interpret the curves correctly; then they constitute an excellent criterion. In a longer paper, in the Astronomischen Nachrichten, it is shown by myself that herein lies a method for the determination of extinction, which does not depend on the momentary condition of the atmosphere. This method should be a valuable supplement to that resting only on the measurements of intensity on extra-terrestrial sources of energy made at widely different zenith distances, since the latter is very unmistakably subject to the disadvantage of having to assume the atmospheric condition unchanged during a rather long time, which according to experience often proves not at all true.

From the data collected by myself I may hope that these determinations of diminution of brightness will be rather productive of results and that they will be extended to the moon as now to the sun, yes, probably to the planets. In the moonlit sky of winter I can perceive not only the "telluric moon corona," but also the isophotic formations, as in the day.

The necessity for perfection of extinction determinations for astronomy, and especially for solar investigation, will materially increase radiation measurement advances—and great advancement is indicated, thanks in no small degree to the cell method. If the astronomer is not able to determine with sufficient accuracy the amount of the permeability of the screen through which he must always look, and slight, transient changes in the same, then oscillations in the solar constant and in distribution of brightness over the sun's disk can hardly be determined with certainty. By masterly investigation Wilsing has fixed the limits within which the constancy of atmospheric condition must remain assured. An exact determination of the extinction coefficient has hardly less significance for meteorology and astrophysics.

SOLAR VARIABILITY AND TERRESTRIAL CONDITIONS.

Literature, especially American literature, lately abounds in investigations on the influence of the period of solar activity. Humphreys and Abbot called it forth by their investigations of climatic change in dependence on solar activity and volcanic eruptions; Huntington seeks to demonstrate a relation between varying distribution of spots over the sun and the air pressure distribution on the earth; according to Clayton the march of temperature in the tropics follows solar activity at an interval of three days; Nansen comes to the conclusion that the temperatures over the continents increase with the number of sun spots, while the temperatures over the oceans fall with such increase; Plaskett finds a relation between solar activity and the velocity of solar rotation; Bigelow even wishes to substitute for the monthly period the 26.68-day period of solar rotation.

There is no lack here and there of objections that the meteorological influences can mask, or be mistaken for such relations, but nowhere does there appear to be clearly expressed what is understood from our preceding discussions—increase in solar activity involves increase in extraterrestrial radiation (apparently only in the short-waved, while the long-waved appears to diminish a little), but at the same time it decreases the transmissibility of the atmosphere, differently for different wave lengths, in contrast to terrestrial disturbances with their coarser particles, which diminish all kinds of radiation approximately equally. The two factors act in opposition, and it must be known how to resolve them in order to arrive at clear results. The observation of sky brightness, polarization, and diminution in brightness from the extraterrestrial light source to the neighboring sky point the way to this. These arguments can be considered only as sidelights over the field, the limits of which are not yet evident.

A brief suggestion fraught with deep significance may close these arguments. During the solar eclipse of May 29 of this year (1919), toward whose results the eyes of the scientific world are directed in expectation of a decision as to Einstein's theory, there appeared, according to news reports, an enormous gas cloud "close to" the sun's limb. Did this cloud lie in reality neither in nor near the sun, but in the earth's atmosphere? According to observations at Davos there began in the early morning of May 29 a considerable optical disturbance, and it faded away typically and very gradually till the middle of June; from other places there are similar reports. Was the refraction change connected with such possible disturbance able to impair the value of the observation, almost reaching the limit of accuracy, for a decision as to Einstein's gravitation theory? Was any attention given to the existence of an optical atmospheric disturbance at the critical points of observation, Sobral, in Brazil and Eddington in western Africa?

SMOKE FORMATIONS IN AIR DRAINAGE.

By CLEVE HALLENBECK.

[Weather Bureau Office, Roswell, N. Mex.]

INTRODUCTION.

In a report upon the temperature and the results of orchard heating in the vicinity of Roswell, N. Mex., on the morning of April 21, 1918, Mr. Hallenbeck wrote as follows:

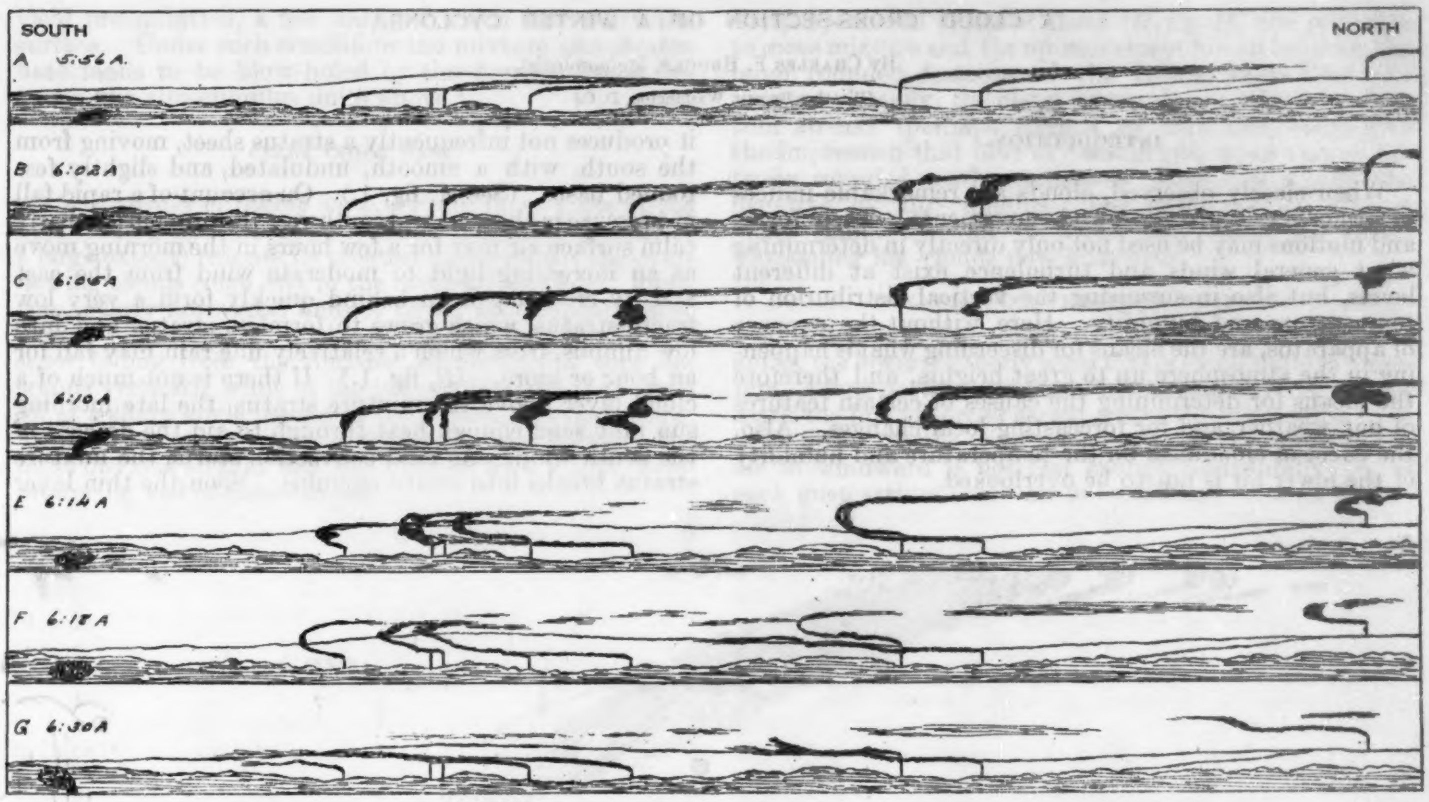
There was one interesting feature of this freeze that is deserving of mention. For four or five hours the air was as nearly calm as I have ever observed for so long a period of time, and the smoke blanket was observed to drift very slowly for a short distance in one direction, then in another direction, frequently moving back over its path. Attempts to photograph heated orchards, after daylight, failed on account of the heavy smoke blanket. This condition (calm and clear) apparently was favorable to a maximum of cooling near the ground. Yet the damage to unheated orchards was mostly confined to the top halves of the trees. Mulberry trees around my residence had their tops badly frozen, while the lower foliage was unharmed. Young corn and beans, not more than 30 yards from these trees, were absolutely unharmed, although in the instrument shelter, about 200 feet away, the temperature was between 32° and 29° for four hours. Many orchardists who had not heated their orchards announced a day or two after the freeze that their crop was only slightly injured, only to discover a week later that the top halves of their trees were nearly bare of fruit.

As the lowest temperature on clear, still nights is usually at the lower elevations, we suggested to Mr. Hallenbeck that he watch the condition in the future so as to ascertain under what general conditions the high-level damage is done. The probable explanation of this interesting phenomena is apparently given in the following paper. Mr. Floyd D. Young has recorded frequent and rapid fluctuations in temperature in the citrus groves at Pomona, Calif., due generally, however, to mixing of the warmer upper air with the cold-surface air. These fluctuations are most marked above the tops of the groves and when there is a strong air draft at the 30-foot level. In one instance recorded, there was a change in temperature of 10° in four minutes at an elevation of 15 feet. At the 5-foot level at the same time there was very little interruption in the steady fall in temperature.—*J. Warren Smith.*

SMOKE FORMATIONS IN AIR DRAINAGE.

The figure here shown was constructed from sketches made on the morning of December 9, 1919. Each of the seven parts of the figure is a duplicate of the others, except for the smoke formations. In the foreground is a screen of orchards and shade trees; in the distance the visible horizon is indicated by a single line. At the extreme right the ground rises into what is known as "North Hill," on which the smokestack of the Military Institute is shown. At the extreme left is "vapor" rising from a flowing irrigation ditch. All the smokestacks are in a general north and south line, except the one at the left, which is about 0.3 mile farther west, while the irrigation ditch was within 100 yards of the observer. The smoke formations were observed and sketched from a point about 1 mile east of the city, the horizontal distance included being, at the line of smokestacks, about 1.6 miles. The general slope of the ground is ESE, but this slope is not visually perceptible east of the city.

It was, of course, impossible to go into detail in making a quick sketch of eight or nine different smoke clouds that were constantly changing, but the formations as shown are sufficiently accurate in general outline. Figure A was drawn from memory.



The drawing is probably sufficiently clear without explanation, but the writer begs to call attention to the fact that the smoke from the right-hand stack and the "vapor" from the irrigation ditch (the highest point and the lowest point, respectively), were the last to change their direction. The "vapor" from the ditch showed no perceptible direction until fully five minutes after the northerly current was fully established at the elevation of the smokestacks. This argues that the front of the advancing current was wedge-shaped, and was considerably in advance of its upper and lower portions. The detached shreds of smoke that, in D and E were apparently stationary, were drifting perceptibly to the south in F and G.

The Weather Bureau instruments are to the west of this line of smokestacks, and on higher ground, and are higher than any of the stacks except the one on the hill at the right. The writer has several times observed such smoke formations as these, in the early mornings, when the wind direction record of the Weather Bureau office showed a change of only 45° or sometimes no change at all, indicating that the drainage current is sometimes so limited in depth as to be entirely below the moderate elevation of the Weather Bureau instruments.

Several cases have been observed of air drainage, occurring after sunrise, that was stopped in the vicinity of Roswell. The reader can, by starting with A, going as far down the series as he chooses, and then reversing the process, form a very good idea of the smoke formations in such cases.

Since the air of the drainage current is colder than the air it replaces (from 2 to as much as 15° F., as shown by thermograph traces) it seems very probable that the "high freezes" which sometimes occur in the Pecos Valley are due to arrested air drainage, or at least to drainage currents that are not sufficiently developed or which do not progress far enough to disturb materially the lowest stratum of air. Friction with the surface of the ground would tend to retard the progress of the lower portion of the drainage current, and when to this is added the retarding influence of the masses of orchards, shade trees, etc., that cover the cultivated belt of the valley, it seems reasonable to believe that the reversal of wind direction at a moderate distance above ground might occur some time before it is felt near the surface. Cases have been observed where the foliage and blossoms in the upper portions of orchards were almost entirely destroyed by freezing when the lower portion, as well as tender vegetation close to the ground, was untouched. In one such freeze, in the spring of 1918, the demarkation was almost abrupt. The writer is informed that such freezes occur less frequently farther down the valley than in the vicinity of Roswell, and the one just referred to did not extend farther than 18 miles south of Roswell.

A series of thermograph records were made during the fall of 1918 and the spring of 1919, at elevations of 5 feet and 24 feet, to ascertain, if possible, the cause of high freezes. When air drainage occurred, it *always* was colder at the upper level than at the lower; the difference usually was not great, but on occasions was as much as 7° and 8°. A few cases were noted where there was a sharp morning fall in temperature at the upper elevation, amounting to 3° to 5°, with no perceptible acceleration of the normal radiational cooling at the lower level. This can be explained only by assuming an overrunning current of colder air. It might be added that a minimum thermometer, installed 2 inches above ground in an improvised shelter, showed readings uniformly 1° to 2° higher than in the shelter 5 feet above ground.

The writer is convinced that the drainage current is nothing more than the down-valley flow of air that has been greatly cooled by nocturnal radiation, and that it originates over the region lying north of the cultivated district. This region is bare prairie, normally quite dry in spring, over which the night radiational cooling would be much greater than in the lower valley where the ground is cultivated, irrigated, and covered with growing crops. This difference between the soil and the soil covering is sufficient to account for the difference in temperature noted after six to ten hours radiational cooling.

A CLOUD CROSS-SECTION OF A WINTER CYCLONE.[1]

By CHARLES F. BROOKS, Meteorologist.

[Weather Bureau, Washington, D. C.]

INTRODUCTION.

When closely observed, clouds are remarkable indices of atmospheric processes and movements. Their forms and motions may be used not only directly in determining what general winds and turbulence exist at different levels, but also in surmising the vertical distribution of temperature and humidity. Here, without the expense of apparatus, are the means for discerning what is happening in the atmosphere up to great heights, and therefore the means for determining the causes of certain features of our weather and for forecasting local changes. Also, the effect of cloudiness on the temperature and humidity of the lower air is not to be overlooked.

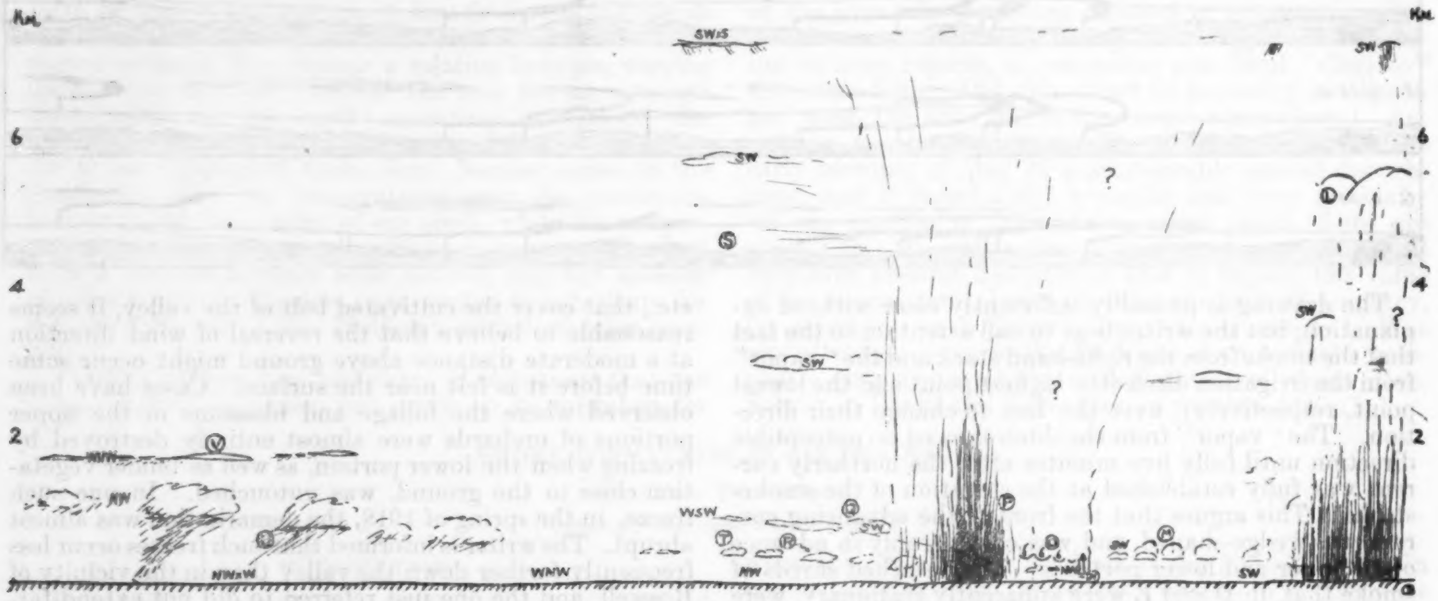


FIG. 2.—A cloud cross section of a winter cyclone.—Second day to third afternoon.

The cloud transformations and movements during the passage of a strong low-pressure area in winter give a fairly clear picture of the internal dynamics of such a storm. The story may be told in four parts: (1) The early stages of the southerly wind, resting in a stratus cloud below and marked by alto-stratus and alto-cumulus above; (2) the forward movement of great masses of falling snow—dripping cirri—from the stongest belt of converging lower winds; (3) the lateral convergence, forced ascent and rainfall as the lower wind changes direction; and (4) the underthrust of the squall-line wedge of the cold NW. wind, which results first in rainfall from the warm SW. wind aloft, and within which the convection, due to the rapid arrival of cold air at a moderate height, causes snow flurries.

THE SOUTH WIND ARRIVES.

Formation of stratus by mixture and of lower nimbus by forced ascent.—As the crest of a HIGH passes eastward a southerly wind sets in during the night, just above the surface layer of stagnant, cold air, and by mixture with it produces not infrequently a stratus sheet, moving from the south, with a smooth, undulated, and slightly festooned base. (See *A*, fig. 1.) On account of a rapid fall in pressure in the west and southwest the previously nearly calm surface air may for a few hours in the morning move as an increasing light to moderate wind from the east and by crowding from behind quickly form a very low fracto-stratus, which grows to formless stratus and into low nimbus, from which a relatively fine rain may fall for an hour or more. (*B*, fig. 1.) If there is not much of a cloud layer above the mixture stratus, the late morning sun may send enough heat through to aid the descent of the south wind. As mild convection starts, the mixture stratus breaks into strato-cumulus Soon the thin layer of cold air at the surface may be rolled away with a parting shower due to the converging south and east winds. Shortly, unless the sun is beginning to sink behind the western clouds, the lower clouds have evaporated, and the warmth and moisture of the air at the surface are suggestive of spring weather.

Growth of alto-cumulus by thermal convection from alto-stratus formed by mixture and forced ascent.—Now, some heavily balled alto-cumulus rising from partly broken, smooth-based alto-stratus are visible. (*C*, fig. 1.) Although the temperature gradient between the underrunning southerly wind and colder wind aloft is becoming steeper, the mixture on the boundary so raises the humidity that a slight amount of local forced ascent usually forms lenticular alto-stratus clouds (frequently with two sets of waves) before the vertical temperature gradient becomes adiabatic (1° C. per 100 m.), and therefore before a convectional interchange would begin between the lower and upper winds in contact. Once a cloud is formed, however, convection will take place if the vertical temperature gradient exceeds only the retarded adiabatic rate (say, 0.6° C. per 100 m.); therefore, the alto-cumulus may grow immediately out of the alto-stratus, whereas they could not form directly. Heavy masses of alto-cumulus formed in this way usually

[1] Excerpted from a paper presented before the Philosophical Society of Washington, Dec. 20, 1919, and the American Meteorological Society at St. Louis, Dec. 30, 1919, and at New York, Jan. 3, 1920. Basis—observations at Washington, D. C., 1919.

yield precipitation, a few drops of which may reach the surface. Under such conditions the mixture alto-stratus base tends to be blow-holed by the down-currents between the alto-cumulus units above.[2]

CIRRI COME EAST.

Cirri, streaks of falling snow.—From those parts of the approaching LOW where convection (probably forced, to a large extent) reaches its greatest development the overflowing clouds come east in the rapid winds aloft. First, thin, nearly horizontal lines of cirrus may appear; those which follow carry hooks. (*D*, fig. 1.) Obviously, snow falling from the rounded cirro-cumulus tops descends vertically while in the top current, and then trails off at a sharp angle behind in the differing current below. As large, streaming masses arrive the sky between the most obvious streaks becomes covered with a thin, halo-producing veil of cirro-stratus.

FIG. 1.—A cloud cross section of a winter cyclone.—First day to second morning.

Alto-cumulus formed by thermal convection on account of steepened temperature gradient caused by cooling of the air by evaporating cirrus.—So much snow falling from aloft and evaporating and cooling the air as it descends steepens the vertical temperature gradient near its lower limits to such an extent that cirro-cumulus or alto-cumulus may form at perhaps 2 kilometers below the cirrus tops. (*E*, fig. 1.) But the snow falls ever lower, and engulfs, or, by forced descent, evaporates, the upper, and then the lower, alto-cumulus. The cloud sheet now looks gray and mottled and the sun fades away behind what is called alto-stratus.

A high level squall cloud and cloud pyramids in front of falling snow.—In the west a heavy bank of strato-cumulus, or roll cumulus, approaches as the sun disappears. As it passes overhead the cause of its formation seems obvious—the snow-cooled air descending with a dense snow curtain just in the rear is under-running the warmer air at the upper part of the southerly wind, and by convection along a belt is making a cloud very similar to that which marks a squall front at the earth's surface. The movements are weaker, however. Just behind the roll are sharp pyramidal pieces of cloud (*H*, fig. 1), due probably to some mixture and the up-movement forced between the large rounded festoons of the falling, snow-filled, air masses. Locally, the cloud pyramids are joined by dark thin streaks (perhaps formed by mixture),—that give the impression that blue sky would give when viewed between rounded nearly contiguous clouds,—essentially the negative of alto-cumulus. The melting of the snow yields raindrops some of which may reach the earth. Thickening low clouds now intervene.

THE WIND-CONVERGENCE NIMBUS.

As the low pressure center draws near to pass on the north, the lower southerly wind makes small shifts in direction. A long north-south line of fracto-stratus (*I*, fig. 1) may mark the line of forced ascent where the wind shifts from SSE. to S. As the wind grows stronger the outlet of the air to windward is not fast enough horizontally, so, as each gust arrives some air is forced up, forming fracto-stratus or strato-cumulus clouds having their long axes east-west (*J*, fig. 1), perpendicular to the direction of compression. The wind shifts two points again, from S. to SSW. Winds of higher velocity are now meeting much more rapidly than on the occasion of the first shift and so heavy north-south lines of strato-cumulus grow, in the evening and merge into a belt of nimbus (*K*, fig. 1), from which moderate rain may fall for the hour it may take the shifting belt to pass. If the wind is still increasing the sky is likely to remain covered with low, heavy clouds. A still further shift to SW. is in store, and where the change is most rapid the cooling by forced ascent of considerable masses of warm moist air by the converging strong winds causes moderate to heavy rainfall during the night. Then, the next morning, through the breaks in the clouds in the rear, may be seen the towering summits of the nimbus in the east (*L*, fig. 1); here probably form the cloud masses which pass eastward before the storm, heralding its approach.

THE SQUALL-LINE AND THE NORTHWEST WIND.

Strato-cumulus by forced ascent of air due to lateral compression of SW. wind in front of squall line.—Now the sky is nearly covered with strato-cumulus and

[2] Cf. "Types of mammato-cumulus clouds," MONTHLY WEATHER REVIEW, June, 1919, 47:398-400.

cumulus as the approaching wedge of cold air behind the squall line compresses the SW. wind laterally. (*M*, fig. 2.)

The squall-line cloud curtain and downward-boiling cloud.—In the west or northwest a low arch of dark cloud comes over the horizon; in a few minutes the wind dies down, and scud in the northwest may be seen rapidly approaching. The arch rises rapidly, and as it passes the zenith it stretches as a straight curtain from horizon to horizon; the northwest squall arrives. Soon the ragged foot of the curtain is silhouetted against the light eastern sky. All along the line, but especially at two or three places, little flecks of cloud suddenly appear just below it and rush up into it as if drawn by a magnet. (*N*, fig. 2.) The cold air from the northwest is forcing the warm air immediately in front to rise at a vertical rate of 5, 10, or more, meters per second. Overhead is a downward-boiling, festooned cloud marking the turbulent wind boundary at the top of the squall. (*O*, fig. 2.)[3] An occasional drop of rain reaches the earth.

Heavy rain resulting from strongly forced ascent.—As the light streak in the east becomes a mere line, rain is setting in, perhaps with a thunderstorm. (*P*, fig. 2.) The heaviest shower of the weather cycle falls during the next quarter of an hour or hour, and as this passes off and the clouds begin to break, the surface wind becomes lighter on account of the backward flow of air from the heavily falling rain. Broken clouds at low levels travel from the NW., and, higher up, from the SW. (*Q*, fig. 2.) As the NW. wind strengthens again compression-forced ascent and surface turbulence form low clouds again, which soon become more or less rounded on top (*R*, fig. 2) by thermal convection as colder air quickly arrives just above the slower-moving air dragging over the surface. After a few hours the precipitation finally stops and the breaking alto-stratus, moving rapidly from the SW., reveals several layers of clouds. (*S*, fig. 2.) In long, changing SW. to NE. lines these last indications of the forced ascent of the SW. wind by the underthrust of the NW. wind gradually pass toward the eastern horizon.

The turbulent strato-cumulus caused by thermal convection; snow flurries.—During the afternoon the lower clouds have become well-defined strato-cumulus (*I*, fig. 2), which disappear at sunset. Before daybreak, however, the semi-stagnation of the surface air and the consequent acceleration of the wind just aloft relieved from the surface drag, has allowed the vertical temperature gradient to become adiabatic, whereupon the wind aloft engages the surface wind and with sudden gusts gets under it and raises it, quickly forming strato-cumulus. After sunrise, the heating of the surface air may intensify this convection and make denser and denser strato-cumulus clouds, from which smudges of falling snow cover the sky (*U*, fig. 2) and occasionally reach the surface as light flurries.

Wave-made, lenticular alto-stratus caps.—The relatively slow-moving convectional masses of air from the clouds so interfere with the free sweep of the winds aloft that they are thrown into waves which disturb the upper boundary of the cold, northwest wind, and, not infrequently, force up this moist layer sufficiently to form long lines of lenticular altro-stratus immediately over the strato-cumulus. These lenticular clouds are sometimes remarkably sharp where forming in front (just before the crest of the wave) and often break into detached wave clouds (waved from SW. by warm current above) where evaporating in the rear. (*V*, fig. 2.)

Temperature prognostics from time of occurrence of strato-cumulus.—Unless the strato-cumulus clouds disappear at or before sunset, colder and colder air is still arriving aloft and a colder night is in store. If no strato-cumuli form on the next morning till several hours after sunrise the cold wave is broken, and a new weather cycle is about to begin.

[3] Cf. fig. 10, ibid., p 400.

CONCLUSION.

It is evident from studies of the appearance and transformations of cloud forms that the different types of clouds are very closely interrelated and pass from one to another form without any recognizable dividing line.

Since our weather is largely the result of the interaction of over- and under-running winds, clouds as indices of such are valuable in showing what is going on and what is to be expected. Cloud observations are finely complementary to pilot-balloon observations, for which there must be clear air and a lack of even intermittently intervening clouds. The whole domain of meteorology has no easier, more interesting, or more promising aspect for observation and study than clouds.

ATMOSPHERIC WAVES.

By F. TREY.

[Abstracted from *Meteorologische Zeitschrift*, vol. 36, pp. 25-28, 1919.]

This note presents the results of a study, by means of kites equipped with meteorographs, of the conditions in the neighborhood of cloud strata, on days when there were present well-defined alternating bands of cloud. The observations were carried out at the Aerological Observatory of Pawlowsk, and are summarized in the following table:

1	2	3	4	5	6	7	8	9	10	11	12
Date.	Temperature, lower layer.	Difference, upper-lower layer.		Wave length.			Height above ground.		Clouds—type.	Direction: N=0°, E=90°.	
				Registered.	Measured.	Computed.	Waves.	Clouds.		Observed.	Computed.
1918.	° C.	° C.	m.p.s.	m.	m.	m.	m.	m.		° °	° °
Jan. 17.	−18	+ 4.8	5.5	550	......	550	800	480	Nb.	90-270	85-265
18.	−20	+ 5.1	5.2	......	570	460	800	520	St.	75-250	79-259
18.	−18	+ 1.0	5.0	2,060	......	2,300	1,400	......	......	......	......
21.	− 5	+ 5.4	6.0	660	......	590	300	230	Nb.	......	......
21.	0	− 2.4	5.0	940	......	900	1,000	......	......	......	......
22.	1	+ 5.2	4.5	360	......	350	400	360	St.	......	......
24.	−15	+ 6.3	7.0	720	......	690	130	......	......	......	......
24.	− 9	+ 1.3	2.5	360	......	420	1,300	......	......	......	......
24.	−14	+ 0.8	3.0	990	......	900	2,400	......	......	......	......
25.	−14	+13.4	9.5	700	......	600	200	......	......	140-320	152-332
Feb. 1..	− 1	+ 6.0	8.5	1,000	1,200	1,070	250	150	St.	44-220 48-210	44-224
2..	− 5	2.7	8.0	......	......	2,200	350	......	......	......	......
3..	......	......	......	......	......	......	......	......	......	48-235	55-235

The observations showed the presence of a more or less sharp surface of discontinuity, above and below which lie several hundred meters of air in which cloud formation takes place. There is then a gradation into a region with the normal temperature gradient. In the disturbed strata occur small but very regular temperature variations which cause waves on the thermogram. It will be noticed that in all but one case a warmer layer is gliding over a colder one.

The data in colums 2, 3, 4 were recorded by the meteorograph; those in columns 6, 8, 9, 10, 11 were obtained by observations from the ground, together with the direction of the wind in each layer of air. Columns 7 and 12 can then be computed. Column 5 was taken from the thermogram. See Wegener, *Thermodynamik der Atmosphäre*, pp. 155-162, 1911.—*E. W. W.*

SNOW CRYSTALS FROM THE CRYSTALLOGRAPHIC STANDPOINT.

By EDGAR T. WHERRY, Crystallographer.

[Bureau of Chemistry, Washington, D. C., Feb. 18, 1920.]

SYNOPSIS.—The magnificent photographs of snow crystals taken by Mr. W. A. Bentley and recently published by Prof. J. C. Shedd, a few of which are reproduced here, (together with some additional ones recently submitted by Mr. Bentley to the writer) bring out interesting and important facts not only in the domains of meteorology and physics, but also in that of crystallography. They confirm the view that ice is ditrigonal-pyramidal in crystallization, and yield considerable information as to the course of the crystallization process under different external conditions.

When a given series of natural phenomena is approached by scientists whose primary lines of work are divergent, their attention is likely to be attracted by entirely different features. The recent article, "The evolution of the snow crystal," by Prof. John C. Shedd[1] is an excellent illustration of this; for he was evidently interested chiefly in the meteorology and the physics involved, and accordingly had little to say about the remarkable crystallographic relations shown by Mr. Bentley's photographs. He did refer, it is true, to a "force of crystallization" being stronger toward the center of the crystal; to the fact that certain of the crystals are "strangely like triangles;" to their obeying a "hexagonal law of crystallization," etc. But these are mere general expressions, which do not apply directly to the crystallographic principles involved. The writer has accordingly prepared this article to call the attention of the readers of the MONTHLY WEATHER REVIEW to this phase of the subject of snow crystals.

As recently pointed out by Dobrowolski[2] and by Mügge,[3] three-fold symmetry has been observed with sufficient frequence on snow and ice crystals to warrant assigning them to the trigonal system of crystallization (the trigonal subsystem of the hexagonal system, as it is called by some crystallographers). In addition, the crystals have proved to be differently developed at opposite ends often enough to place them in one of the hemimorphic classes of this system. The fact that ice does not rotate the plane of polarized light shows that it belongs to the particular class known as the ditrigonal-pyramidal (also termed the ditrigonal-polar or the trigonal holohedral-hemimorphic class), the one of which the mineral tourmaline is the best known example.

The trigonal system is characterized by the presence of two kinds of axes or directions of development, three of one kind and one of the other. The three axes of the first kind lie in a plane, crossing each other at angles of 60°; the other, called for convenience the unique axis, lies perpendicular to this plane. The unique axis is an axis of threefold symmetry; that is, every feature of a normal crystal of this system occurs at least three times at equal angular distances around this axis. Certain features may appear to be repeated six times around this axis, and the crystals may then simulate those of the hexagonal system, which differs from the trigonal only with respect to the degree of symmetry of the unique axis.

The pyramidal class of this (as of any other) system is characterized by the fact that opposite ends of the unique axis are crystallographically unlike. Most snow crystals are so developed that this property of the unique axis is obscured, but occasionally it is exhibited in a striking manner, as in some of the figures discussed below.

[1] MONTHLY WEATHER REVIEW, Oct., 1919, 47: 691-694.
[2] Arkiv för Kemi, Mineralogi och Geologi, 6, No. 7, 1916.
[3] Centralblatt für Mineralogie, Geologie, und Paläontologie, 1898, pp. 137-141.

Crystals in general are bounded by more or less plane surfaces, known as the crystal faces, which lie in various positions with reference to the axes of the crystal. Groups of faces bearing similar relations to the axes are called forms; and the relative development of different forms is referred to as the habit of the crystal. The habit of most snow crystals is tabular in the direction of the unique axis, the form known as the base being dominant. The boundaries of the tabular crystals are determined by forms known as prisms, which by definition are forms which lie parallel to the unique axis. The actual faces of the prisms are usually not in evidence,

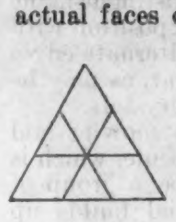


FIG. 1.

FIG. 2

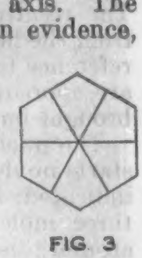


FIG. 3

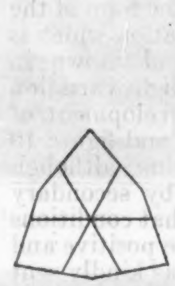


FIG. 4

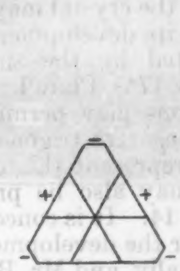


FIG. 5

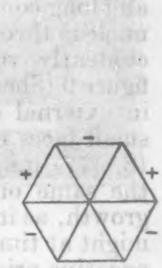


FIG. 6

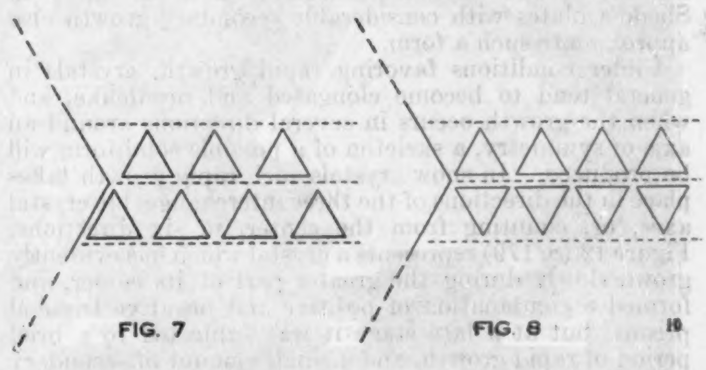


FIG. 7 FIG. 8 10

but the shapes of the prism cross-sections are prominent. Three different types of prisms are possible in the ditrigonal-pyramidal class, known respectively as the trigonal, the hexagonal, and the ditrigonal prisms. The cross sections of these and their positions with reference to the axes are shown in the following figures:

Figure 1 represents the cross section of the simple trigonal prism; the sides of the triangle lie, it will be noted, parallel to the axes within. Figure 2 is the same form, but lies in reversed position and is accordingly crystallographically distinct. For convenience the prism in the first position will be called positive, that in the second negative. Figure 3 is the cross section of the hexagonal prism possible in this crystal class. Its sides lie perpen-

dicular to the axes within, and are accordingly not parallel to those of either trigonal prism. Figure 4 is the cross section of the ditrigonal prism, in which two edges lying at an angle of greater than 60° replace each edge of the trigonal prism cross-section. A negative ditrigonal prism is of course possible also, but has not been figured, as its relations are obvious. This hexagonal prism (with sides perpendicular to the axes) and both positive and negative ditrigonal prisms occur on crystals of the mineral tourmaline, but none of these prisms appear to have been observed on snow crystals.

Figure 5 outlines a combination of a positive and a negative trigonal prism, the former being dominant over the latter. In figure 6 the same two prisms are combined in equilibrium position, neither being dominant. The resulting outline is geometrically indistinguishable from the hexagonal prism, but differs in its position with reference to the axes of the crystal. The alternate edges are, moreover, crystallographically dissimilar, as may be brought out by certain features on actual crystals.

The nucleus from which the growth of a snow crystal starts no doubt consists of a single ice molecule, which is indicated by the chemical evidence to be a group of three molecules of H_2O. As new material builds up around this nucleus, several different things may happen. If the growth is very gradual, relatively uninterrupted, and long continued, the crystal may retain the form of the nucleus throughout its development, a situation which is evidently represented by the snow crystal shown in figure 9 (Shedd's No. 174), Plate I. Some slight variation in external conditions may permit the development of small faces of the negative trigonal prism, and figure 10 (S. 177) may well represent this combination; although the same outline may also be produced by secondary growth, as in figure 14. It is conceivable that conditions might at times favor the development of the positive and negative prisms equally, and Mr. Bentley has kindly sent a photograph of a crystal apparently exhibiting this relation, which is reproduced in figure 11 (Bentley's No. 1637); the central portions of some of those in Shedd's plates with considerable secondary growth also approximate such a form.

Under conditions favoring rapid growth, crystals in general tend to become elongated and needlelike, and when the growth occurs in several directions around an axis of symmetry, a skeleton of a possible solid form will be produced. In snow crystals such rapid growth takes place in the directions of the three interchangeable crystal axes, or, counting from the center, in six directions. Figure 12 (S. 179) represents a crystal which has evidently grown slowly during the greater part of its career, and formed a combination of positive and negative trigonal prisms; but at a late stage it was subjected to a brief period of rapid growth, and a small amount of secondary material was deposited in the axial directions. Shedd's figure 67 is a good example of a somewhat more advanced stage in the same process, and figure 111 and others show further advance. In figure 13 (B. 1749) the secondary growth has subsequently been subjected to still different conditions, and has tended to consolidate. And in figure 14 (S. 144) consolidation has been completed, although the trigonal outline has been preserved. In Plate II, figure 15 (B. 1995), on the other hand, the secondary growth began at a comparatively early stage, the trigonal nucleus being small; and the symmetry of the secondary growth is completely hexagonal. The interference of lateral rays, resulting in change of their direction, is an interesting feature of this crystal. Figure 16 (S. 146) shows similar relations, but is further consolidated.

In figures 17 (B. 3014) and 18 (S. 109) the central portions have to all appearances a fairly definite hexagonal symmetry, but that they are made up of a positive and a negative trigonal prism in equilibrium is clearly indicated by the unmistakable trigonal plan of the secondary growth.

The majority of snow crystals show, however, no sign of trigonal symmetry. The trigonal nucleus is vanishingly small; secondary, rapid, growth was started very early in the history of the crystal, and the resulting figures, whether remaining in skeleton form or consolidated, exhibit highly perfect hexagonal symmetry. Typical examples are shown in figures 19 (S. 5) and 20 (S. 84), but numerous others in the series as originally published would serve equally well to illustrate this feature.

One of the principal unsolved problems in connection with snow crystals is the practically perfect bilateral symmetry shown by the lines of the secondary growth, as well brought out in several of the crystals figured. (Compare figs. 16, 19, and 20.) For, if this secondary growth were appreciably influenced by the fact that alternate edges of the nucleus are crystallographically dissimilar, there should be a definite, consistent, asymmetry of these growth lines, oriented in such a manner that a trigonal aspect would be imparted to the crystal as a whole.

There are two alternative explanations of this relationship. According to the one, under conditions of rapid growth the crystallographic dissimilarity of alternate edges of the figure tends to be obscured, the secondary material depositing in parallel position upon the six corners of the nucleus, and retaining parallelism throughout its growth. The other explanation involves the assumption that the lines of growth are twinning directions, and that the material depositing upon their opposite sides lies in twin position; in this case bilateral symmetry of these lines would be the normal relationship, and no crystallographic properties would have to become obscured because of external conditions. The difference between these explanations, along a greatly magnified portion of a single growth axis, is shown, respectively, in the diagrams figures 7 and 8. It seems impossible, however, to decide between these two explanations in the present state of our knowledge.

Other degrees of symmetry are occasionally shown by snow crystals as the result of more or less accidental conditions of growth, and it seems worth while to discuss a few of these also. The most interesting in the recently published collection (and some new ones furnished by Mr. Bentley) are here reproduced, as figures 21 to 30, in Plates III and IV.

Figure 21 (S. 192) shows practically complete suppression of two opposite growth directions, giving a four-rayed figure; although as the rays diverge at the usual 60° angles, the symmetry is but twofold; that is, a given configuration occurs but twice in a revolution around the unique axis. Figure 22 (B. 1209) shows the same phenomenon, but consolidation of the crystal is much more complete. In figure 23 (S. 186) the suppression, though corresponding in position to the two preceding ones, was but temporary, and the material subsequently deposited has made, as it were, an effort to catch up with that in the more favored directions. Figure 24 (B. 173) represents a remarkable instance of completion of such a partial development. Its central portion shows clearly the original suppression of two opposite growth directions; but the deficiency has been made up entirely by further growth, in such a way that the final symmetry is strongly trigonal.

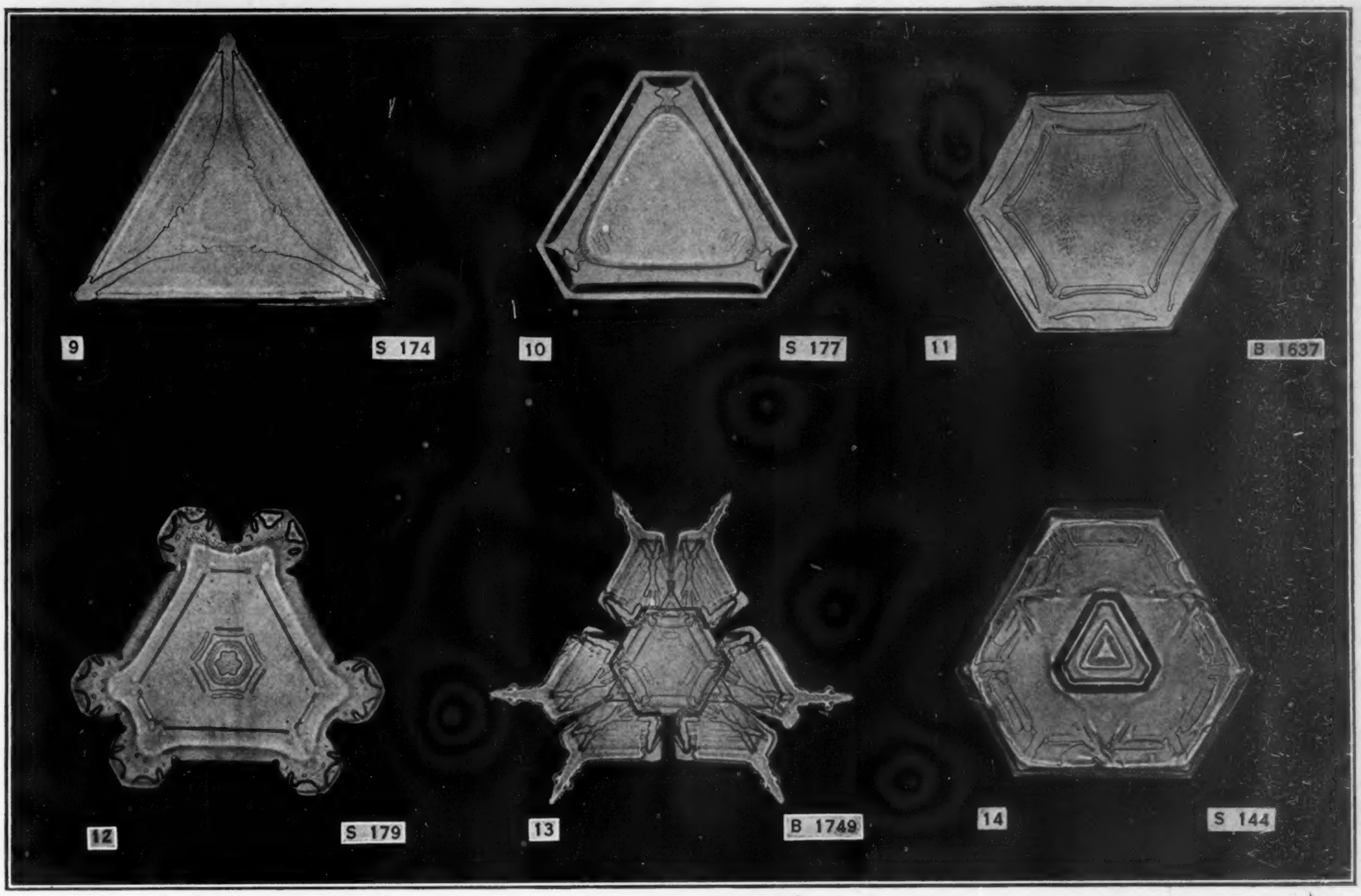
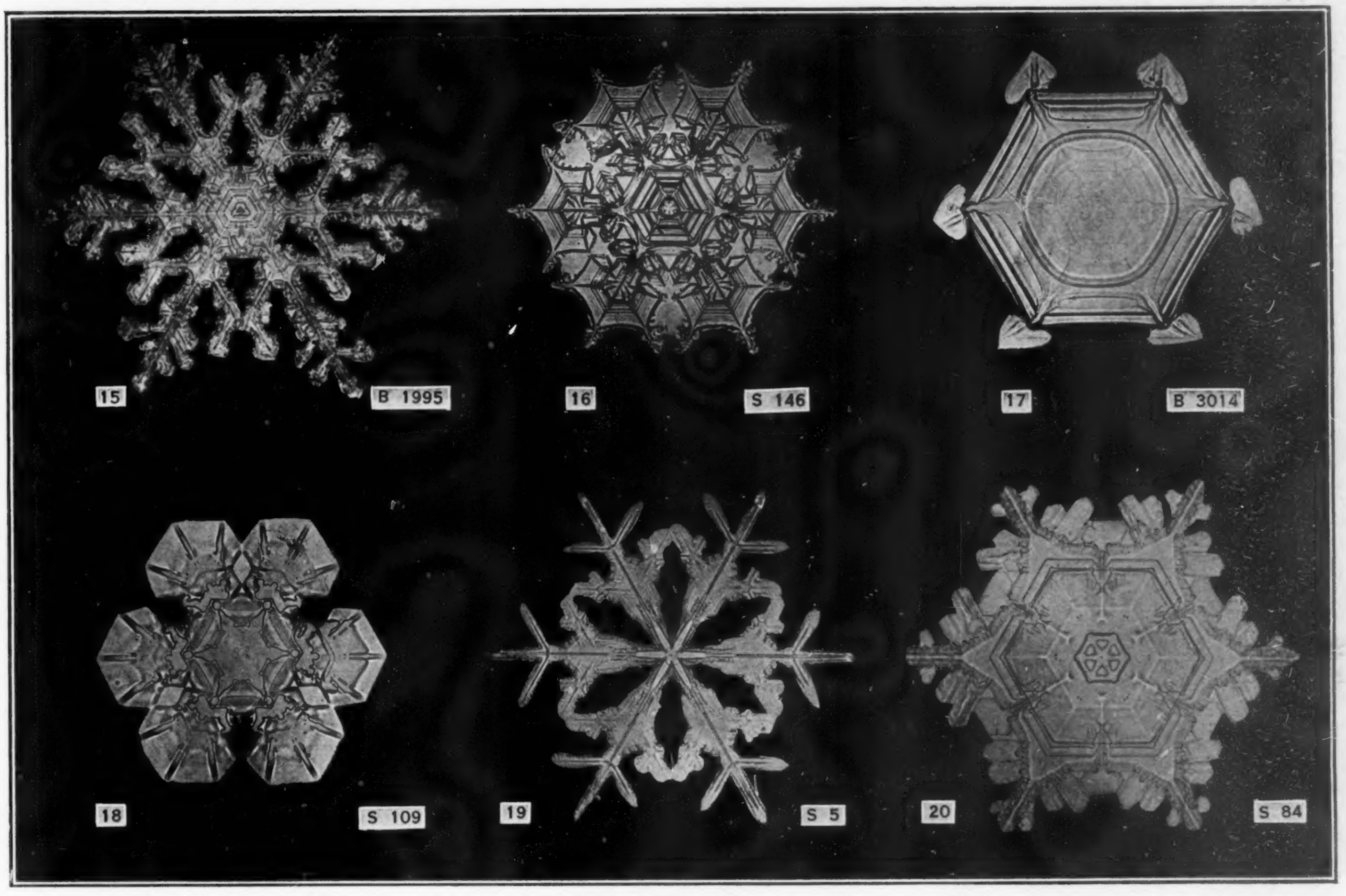


PLATE I.



PASTE II.

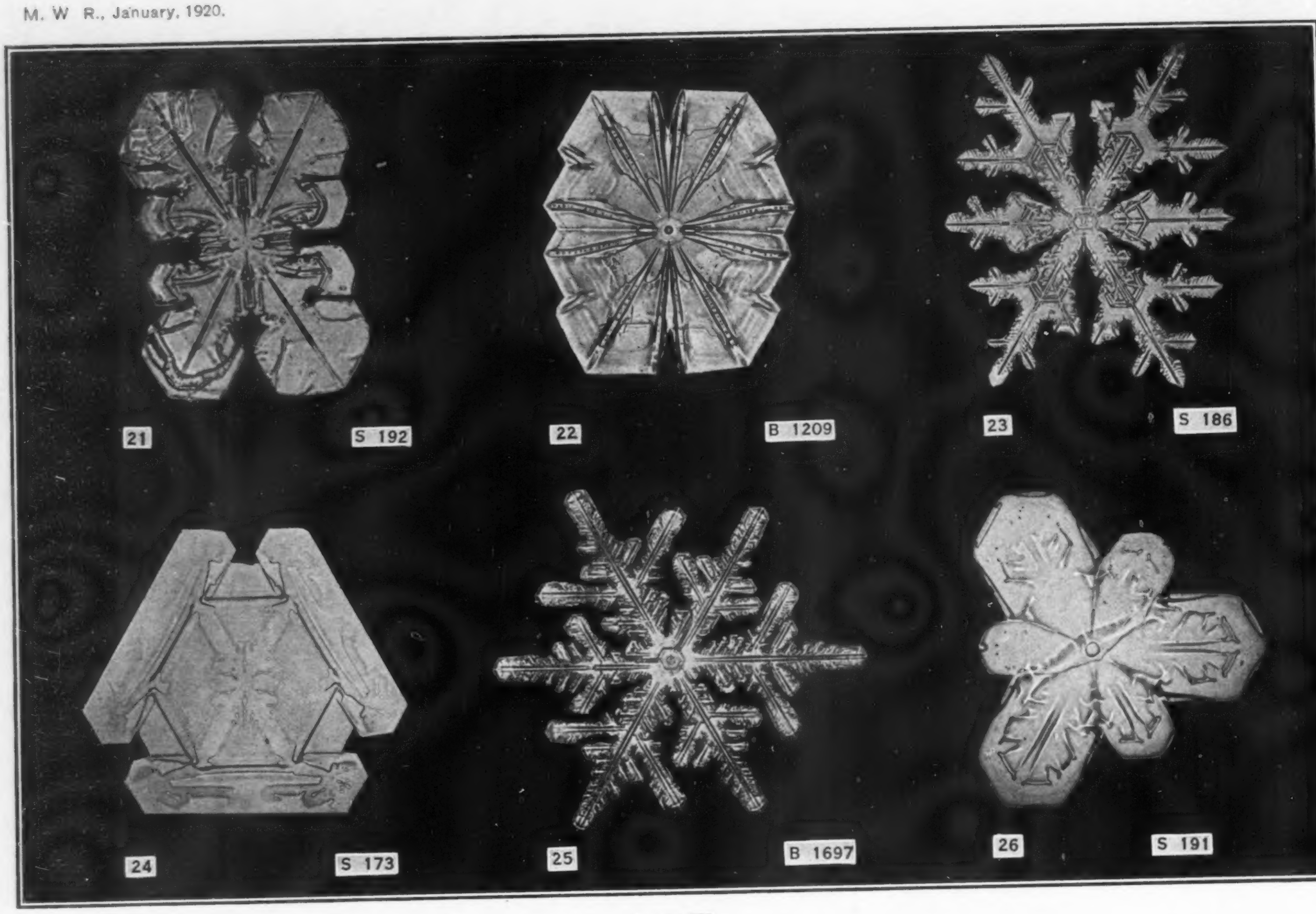


PLATE III.

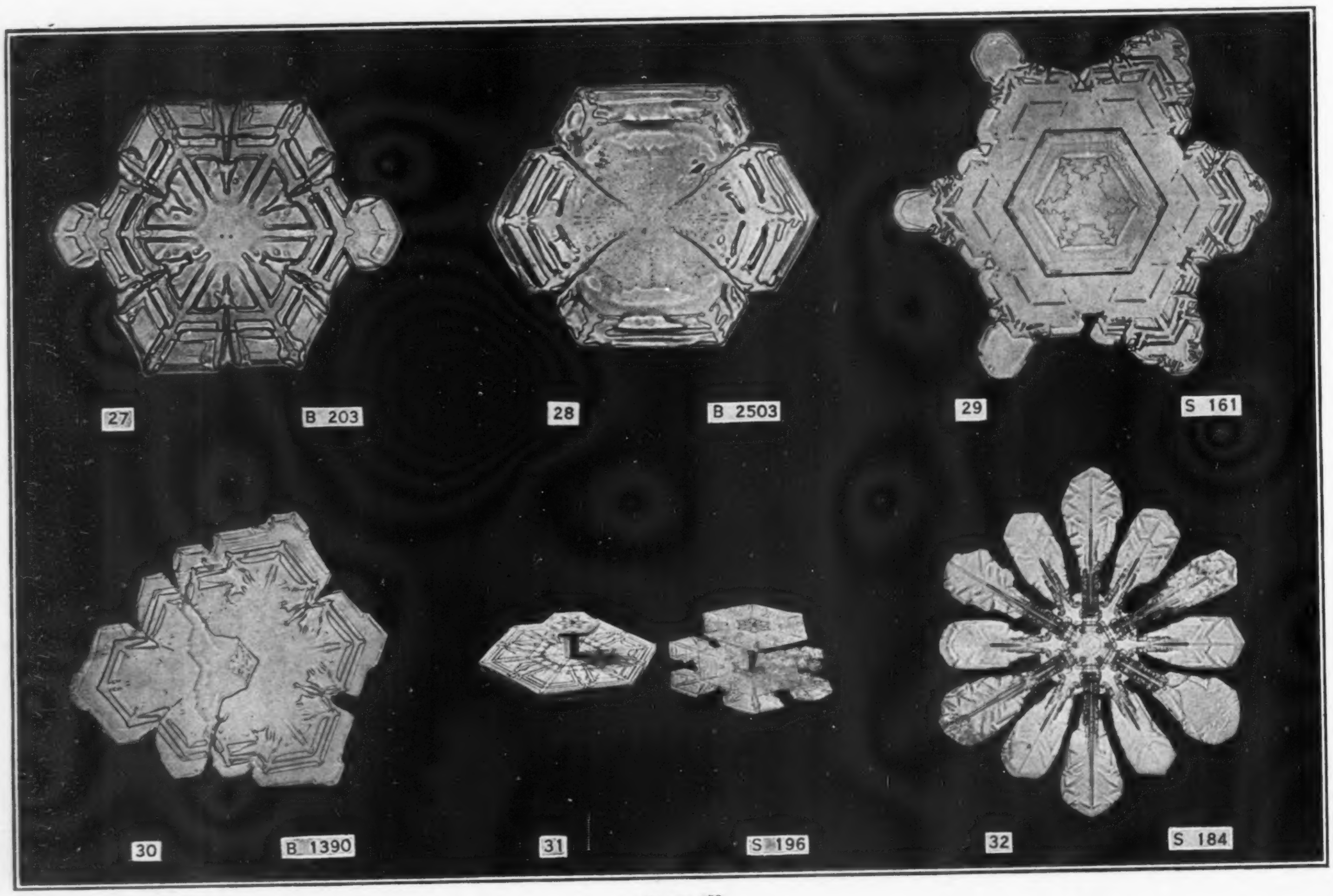


PLATE IV.

In the next two figures, 25 (B. 1697) and 26 (S. 191), growth has been delayed or temporarily suppressed along three, alternately placed, directions, yielding apparently trigonal forms, the apexes of which lie at 30° from those of the actual trigonal prisms. The symmetry around the unique axis is here threefold, but the arrangement of the directions of delayed growth with reference to the crystal axes shows that this is not an expression of the symmetry of the substance, but is essentially accidental.

A still greater number of directions of suppression or delay of growth are shown by figures 27 (B. 203-b) and 28 (B. 2503) (No. 178 of Shedd's series is another instance of the same thing); in these, four directions have been suppressed, and two opposing ones favored. In No. 27 this has occurred only in the last stages of growth; in No. 28 at a much earlier time. The result is a marked development of twofold symmetry around the unique axis. Still less symmetry is shown by figure 29 (S. 161), in which there has been a suppression of three adjacent growth directions, giving a figure possessing only bilateral symmetry with respect to one of the three like axes, placed horizontally in the figure. Figure 30 (B. 1390; also Shedd's 187) shows similar bilateral symmetry as a result of having only two growth directions suppressed, these lying 120° apart.

Interference between closely adjacent crystals is of course one effect capable of producing some of these suppressions of growth. And Mr. Bentley points out that crystals like figure 30 often show overlapping of the opposite portions, indicating that they have been subjected to some disruptive force. But the causes of these "accidents" which result in diminished symmetry can in general not be explained in detail.

Finally, a few crystals in which the unique axis is so developed that the crystallographic difference between its extremities is brought out remain to be considered. In figure 31 the tabular crystals at opposite ends of the central column are in the one case different in size, in the other different in outline as well. Figure 32 is evidently merely another illustration of a similar effect, the elongation of the unique axis being but slight. Here, however, the crystals belonging to the opposite ends have apparently pushed each other aside, so that they now lie at 30° from one another. The property of ice crystals of exhibiting gliding on the basal plane without disruption has permitted them to remain attached, and an apparent 12-rayed crystal is the result, the crystallographic dissimilarity of the opposite ends being brought out by the slightly different size of the alternate rays.

EXPLANATION OF PLATES I TO IV.

All the figures except the last two are placed with their crystallographic axes in corresponding directions, one right and left, two others crossing it at 60° angles, and the unique axis perpendicular to the paper.

Plate I.

Figure.

9 (Shedd's 174). Simple trigonal prism without apparent secondary growth.

10 (Shedd's 177). Positive with subordinate negative trigonal prisms, without apparent secondary growth (this may be present but obscured).

11 (Bentley's 1637). Positive and negative trigonal prisms in equilibrium; no apparent secondary growth, although this may be present but merely obscured, as suggested by the symmetrically arranged air bubbles near the center.

12 (S. 179). Like 10, with secondary growth beginning along six directions.

13 (B. 1749). Like 12, with secondary growth well advanced.

14 (S. 144). Like the two preceding, but with secondary growth consolidated.

Figure. *Plate II.*

15 (B. 1995). Small trigonal center, with subsequent growth showing hexagonal arrangement; interference of lateral rays also shown.

16 (S. 146). Like 15, but with secondary growth well consolidated.

17 (B. 3014). Central portion apparently hexagonal, but the crystallographic dissimilarity of alternate sides shown by the trigonal arrangement of the outermost secondary growth.

18 (S. 109). Like 17, with secondary growth well consolidated.

19 (S. 5). Trigonal center vanishingly small, and secondary growth showing hexagonal arrangement, with marked bilateral symmetry along rays.

20 (S. 84). Like 19, with secondary growth well consolidated. (The features shown by figures 19 and 20 are those of most frequent occurrence in snow crystals.)

Plate III.

21 (S. 192). Practically complete suppression of growth along two opposite lines, resulting in two-fold symmetry.

22 (B. 1209). Like 21, with secondary growth well consolidated.

23 (S. 186). Like 21 and 22 at the outset, but subsequent growth in originally suppressed directions has nearly caught up with that in the favored directions.

24 (B. 173 through oversight given as S. 173 in the plate). Like 23, but with subsequent growth so caught up and consolidated as to have complete trigonal symmetry.

25 (B. 1697). Growth delayed along three alternately placed directions, resulting in apparent trigonal symmetry.

26 (S. 191). Like 25, but with secondary growth more consolidated.

Plate IV.

27 (B. 203-b). Suppression of secondary growth along four lines, resulting in twofold symmetry.

28 (B. 2503). Like 27, but the suppression has occurred at an earlier stage.

29 (S. 161). Suppression of secondary growth along three adjacent directions, giving only bilateral symmetry on a single axis.

30 (B. 1390). Suppression of secondary growth at an early stage along two directions lying 120° apart, the result being similar to that in 29.

31 (S. 196-b). Two crystals showing crystallographic dissimilarity of the ends of the unique axis by the more extended growth of one attached plate as compared with the other.

32 (S. 184). Like the preceding, but with very short column, and with the crystal belonging to one end of it turned at 30° with respect to that belonging to the other end; crystallographic dissimilarity of the opposite ends of the unique axis distinctly shown by the difference in development of the alternate rays.

WOULD A LARGE RESERVOIR INCREASE RAINFALL?

The Central Office of the Weather Bureau recently received a request from a foreign government for an opinion as to whether it would be worth while to construct a large reservoir to affect favorably the rainfall of the immediate area in which it would be located. The climatic conditions of the region in which the construction of the proposed reservoir is being debated are rather peculiar since it is a tropical region of low rainfall and occasional severe droughts with the ocean on one side and otherwise surrounded by regions of rather abundant rainfall.

In seeking for analogous conditions in the United States the following, while not similar in all respects to those of the country in which the reservoir is proposed to be created, offered the most direct evidence. The cases considered were the creation of Salton Sea, in California, the building of dams and the reservoirs formed thereby in Minnesota and finally the probable influence of the Great Lakes on the precipitation of the Lake region.

These cases were considered briefly and the precipitation in the cases of Salton Sea and the reservoirs of Minnesota both before and after their creation was tabulated.

The average rainfall of Arizona taken from climatological data for that State shows more rain after 1906,

the year that Salton Sea was formed, than before, with the exception of the dry year of 1910. The data are, however, not strictly homogeneous, since the number of reporting rainfall stations in later years was much increased and, moreover, the proximity of the Gulf of California to Arizona, a body of water vastly greater than Salton Sea even at its maximum, seems to vitiate the argument that the presence of Salton Sea materially affected the rainfall of Arizona.

In the case of Minnesota the yearly averages for a period of 32 years does not show any progressive increase in the rainfall of that State; on the contrary, the greatest deficiency in precipitation during the period occurred in 1910, several years after the completion of the reservoirs.

A consideration of the probable effect of the Great Lakes led to the conclusion that an increase of 2 or 3 inches in the annual precipitation might reasonably be ascribed to the moisture supplied by the Great Lakes.—*A. J. Henry.*

THE DESICCATION OF AFRICA.

[Review reprinted from *The Geographical Journal*, Feb., 1919, vol. 53, pp. 122-123.]

Papers on the increasing aridity of areas in the south and west of Africa have recently been noticed in this *Journal* (vols. 50, p. 30, and 51, p. 404), and a recent Johannesburg publication by Prof. E. H. L. Schwarz, which we have received, dealing with the continent as a whole in the same relation, will at least be useful in bringing into prominence a variety of interesting questions, geographical, meteorological, and engineering. The evidence is held to be incontestable that the Sahara Desert within the historic period and the Kalahari Desert much more recently were well watered and thickly peopled, and that the change to present day conditions has been brought about by alterations in the river system of the continent through headstream erosion of the short, rapid coastal streams, which by cutting back into the coastal mountain rampart have captured the waters of great inland rivers. In this way, it is held, has the Niger been diverted from a straight northerly course across the Sahara, fertilizing a wide extent of border country, into the bent curve which the river describes today with disastrous consequences to northwest Africa. That local desiccation of parts of the continent is in progress as a result of its peculiar physical structure is no doubt possible, and its explanation by headstream erosion altering the drainage systems is more plausible than one which attributes it to progressive decrease of rainfall—a supposition difficult to admit on climatological principles in default of indisputable evidence. Having considered the apparent facts of desiccation and their causes, the author goes on to discuss somewhat ambitious schemes for the amelioration of climatic conditions in the waterless regions of Africa which are alleged to be steadily gaining in area in consequence of the pernicious hydrographic régime under which the continent lies. The measures outlined consist of engineering schemes for enlarging the areas of Lake Chad in the Sahara and Lake Ngami in the Kalahari to something like former dimensions. The project for North Africa of diverting Congo waters at Stanley Pool is dismissed as too costly to be feasible at the present time, but that for South Africa (to which reference was made in the *Journal* for May 1918, p. 337) is urged as being quite practicable and of pressing importance. Were we disposed to grant the possibility of creating an artificial reservoir some 15,000 square miles in area (as to which opinions will certainly differ), the author's contention that it would add greatly to the humidity of the air over South Africa and so tend to mitigate the destructive character of desert winds is no doubt sound; but one can not give unqualified assent to his further contention that the evaporation from such an inland reservoir must necessarily "supply rain clouds for the whole of South Africa," rendering sterile tracts fertile. The primary raison d'étre of the African deserts, both north and south, is their location in the belt of trade winds which, whether they blow over land or sea, are rainless winds except where their course is obstructed by a range of mountains, as in the case of the Drakensberg system on the eastern side of South Africa itself. In South Africa the really droughty region with less than 10 inches of rain per annum extends from about the middle of the Bechuanaland Protectorate westward right to the shores of the Atlantic; and no estimate of the capacity of a large "evaporating dish" for increasing either the local or general rainfall of the country would be of much value that was not based upon a very intimate local knowledge (of which evidence is not produced in the paper under notice) of the precise conditions in which such rain as does fall is generated.

THE PROGRESSIVE DESICCATION OF THE COLONY OF SENEGAL.

By Charles Rabot.

[Abstracted from a discussion of the memoirs of Henry Hubert, Progression du dessèchement dans les régions Sénégalaises, *Annales de Géographie*, Paris, 1917, No. 143, in *La Géographie*, 1918, No. 2, pp. 111-113.]

Important researches in the variation of climate in Senegal, the French colony in West Africa, have been made by Henry Hubert. The geological deposits are of such a nature as to indicate that the climate in comparatively recent times has been wet; but the deposit of sand which covers the sandstone indicates that at present the tendency to dryness is increasing. The dry river valleys, old fords, the remains of crocodiles and fishes far inland, the decreasing distance from the mouth to the head of navigation of the rivers, and the decreasing commercial activities of the colony are current testimony of the progressive desiccation of the land. Towns which formerly were thickly populated are now deserted, sand dunes which formerly were quite permanent now show a tendency to shift, and water holes are disappearing.

The apparent advances and recessions of glaciation in the Alps within historic times, indeed in very short periods, are evidences of successive climatic changes which can be more easily manifest in the high mountains than in the plains country. Nevertheless, the relation between such periods in the Alps and the changes in Senegal can be traced, although of far less amplitude in Senegal. This would indicate that the present era of dryness may be again followed by one of wetness.—*C. L. M.*

HOW RAINFALL DATA MAY BE USED FOR DETERMINING ROAD CONDITIONS.

By TRUMAN G. SHIPMAN, Observer.

[Weather Bureau Office, Little Rock, Ark., Jan. 5, 1920.]

[Author's Abstract.]

Realizing the need for up-to-date, complete, and accurate information on highway conditions, an effort has been made to determine the effects of rainfall on highways so that telegraphic reports of rainfall can be utilized in making up the daily, highway weather service bulletin. The following results were obtained after a study of replies to questionnaires mailed to cooperative observers, crop correspondents, meteorologists, engineers, and others familiar with highways and weather conditions in the communities in which they live. The results apply to dirt roads in Arkansas and mainly to spring, late autumn, and early winter conditions.

It should be remembered that all the results are averages, and that only reliable estimates in measureable amounts of precipitation were used to obtain the figures. The average opinion of the correspondents is that 1.38 inches of rainfall make dirt roads muddy; those located in the lowlands estimated that 1.13 inches was the required amount; in the uplands, 1.51 inches. They estimated that 2.78 inches of rainfall make dirt roads very muddy; those in the lowlands, 2.25 inches; and those in the uplands or hills, 2.90 inches. The variation for surface conditions is 29 per cent in both instances. It is interesting to note that it requires about twice as much rainfall to make dirt roads very muddy as to make them muddy. The estimated amount required to make dirt roads impassable averaged 4.04 inches, varying from 3.57 inches for the lowlands to 4.35 inches for the hills and uplands. Here the variation is 22 per cent for surface conditions. By impassable is meant that automotive and the heavier horse-drawn vehicles can not get through, but the lighter horse-drawn vehicles usually can. Many of the correspondents reported that their highways seldom became impassable on account of mud, therefore these figures apply only to highways that do.

The estimated length of period with intermittent light-to-moderate rains and cloudy weather that make dirt roads muddy was 2.6 days; very muddy, 5 days; impassable, 6.5 days. These figures may be used in counting accumulated amounts of rainfall when sufficient precipitation to produce conditions to be reported does not occur in a shorter time. There was not much variation in length of period for surface conditions, except that the time necessary to produce impassable conditions was a little longer for the bottoms. Here the accumulated amounts are more effective in producing results on account of soil and drainage and one more day's rainfall may be used in counting the total. The time required for roads to become passable after the cause of impassability ceases was estimated at about a week, being a little longer in the bottoms.

These results can be used to determine the conditions of highways from telegraphic reports of rainfall when mail reports are missing or incomplete. If the mail report indicates a fair condition of roads and 1.13 inches of rain fell over the district according to the telegraphic reports since mailing the card, the roads should be reported "muddy." If the roads were muddy and 1.12 inches (2.25 inches minus 1.13 inches) were telegraphed since the card report, the report should be "very muddy." If the roads were very muddy and 1.32 inches (3.57 inches minus 2.25 inches) were telegraphed since the card report, they should be reported "impassable." Lowland figures are used in the above illustration. A plan like this is needed more in the winter time than at other seasons because roads are muddy or very muddy much of the time and small amounts of precipitation make important changes in highway conditions. Snowfall is seldom a factor in road conditions in Arkansas except when melted.

EXTRAORDINARILY HIGH BAROMETER READINGS IN BERING SEA, JANUARY 17, 1920.

Capt. Arthur H. Mellick, of the United States fisheries ship *Eider*, has submitted the following note, which is interesting in connection with the abnormally high pressure prevailing over Alaska and the Aleutian Islands and the unusually low pressure (barometer 29.64 inches Jan. 17) at Honolulu during January (see p. 45, below):

On the 15th day of January we left Unalaska for the Pribiloff Islands. The barometer then registered 30.62. By midnight it was 30.66 [inches]. On the 16th at midnight it showed 31.00. At noon on the 17th it showed 31.20, at 4.00 p. m. it was above the registered marks, and at midnight it was back to 31.20, where it remained until 4.00 a. m. on the 19th, when it commenced to fall very slowly; and even now, with a northeast gale blowing and heavy snowstorm, it is still 30.68. Such barometer readings I have never seen in this part of Alaska before with all the years that I have been in the country. While at the Pribiloff Islands the sea was very calm and light northeast breeze, but not a particle of ice was to be seen, although it felt as though it was not very far away.

ABSTRACTS, REVIEWS, AND NOTES.

THE OUTLOOK OF METEOROLOGICAL SCIENCE.

By Sir NAPIER SHAW.

[Excerpts, presidential address "Meteorology: The Society and its Fellows," Royal Meteorological Society, Jan. 15, 1919.[1]]

THE POSITION BEFORE THE WAR.

Looking backward, we must take account of a promise of remarkable activity in all branches of meteorology. Even if there had been no war, the last five years would have been fruitful years in the development of the science. The progress of aerial navigation, already begun in 1914, promised unexampled opportunities in the comparatively new study of aerography, in addition to those which meteorologists had previously made for themselves.

THE SHOCK OF WAR AND THE REACTION.

The first effect of the war was to curtail the work of of the meteorological office, but soon the demands for more numerous and more complete observations, particularly of the upper air, brought on an activity exceeding that prior to the war. There was a strong call for more general knowledge of meteorological methods and results. Suggestions almost forgotten and new ones were applied and found so helpful that "it may be that, in the near future, no meteorological observatory will be regarded as really complete if it does not possess a cinematograph camera, a searchlight, a range finder, and a chronograph, besides a kite balloon, a gun and ammunition, and crews to use them." Also, there was realized "a need for a trained meteorologist, not for the purpose of foretelling the weather, but for making the best use of the available information."

Throughout the whole course of the war we were constantly reminded that what was standing in the way of an effective use of past experiences of weather in all parts of the world was a lack of general knowledge of the common methods of meteorological study and of the principles deduced by their aid. Until this position is secured, every letter in reply to a simple inquiry must be prefaced with an explanation of what you mean by an isotherm, an isobar, the exposure of an anemometer, and even the difference between the points of the mariner's compass and the geographical orientation, and every popular lecture must begin, and generally has to end, with a recitation of rudimentary ideas.

Great impetus was given to studies of the upper air, for "meteorologists, physicists, and mathematicians alike are agreed that the key to the meteorological situation throughout the atmosphere is the relation of the wind to the barometric pressure at the same level."

LOOKING FORWARD: THE NEED FOR METEOROLOGICAL ORGANIZATION AND A PROFESSIONAL CAREER.

After this hurried glance at the past let us look forward to the future. The first thing that we realize is that with the multiplication of meteorological services there is urgent need of proper provision for training, and for the organization of a meteorological profession which will offer a graded career to men of ability, and provide the nucleus of an establishment available for various kinds of meteorological work in any part of the world. A trained meteorologist must have an adequate knowledge of mathematics and physics; we have satisfied ourselves during the war that those qualifications are indispensable, but they are not in themselves enough; there must be added to them a penetrating acquaintance with the facts of meteorology and the way in which they are obtained, as well as a knowledge of the principles of the science and its applications.

THE PRELIMINARY TRAINING REQUIRED FOR A PROFESSIONAL CAREER.

Here perhaps it is desirable to make it clear that the practice of the science of meteorology includes the process of observing, of the first part; the compilation and summarizing, in maps or otherwise, of the facts of weather, of the second part; the application of meteorological principles, which includes the forecasting of future weather, of the third part; and the development of the science of meteorology, of the fourth part. Any one of the first three may be pursued according to recognized canons of procedure with satisfactory results; every one of them is indispensable, and history is my witness that all three of them may be pursued simultaneously without any effective recognition of the fourth part, which forms our only avenue to the comprehension of the secrets of the sequence of weather.

There is no doubt that the processes of weather are simply examples of the dynamics and physics of the atmosphere, and though special methods may be required for the special problems with which we have to deal, yet the ultimate object of all our observations and all our summarizing is to lead up to an insight into the physical processes which constitute the changes in our weather; all our forecasting is the anticipation of the results of these changes. The method of forecasting by empirical rules and experience is simply a stage in the classification of the physical processes. It leads, as we know, to excellent results in the hands of experienced practitioners. It can be acquired by persons of ordinary education, but its capacity is limited, and the limit is very soon reached. To carry it further, or to make out the true inwardness of its application in special cases, we must depend upon our knowledge of the dynamics and physics of the atmosphere. Sometimes we see it suggested that additional observations of some element or other in the free air will relieve us of the arduous task of making out the dynamical process, but it is not in the least likely that we can be saved in that way from using our brains. Each new fact throws new light upon the general problem, but at the same time it generally introduces a new element of complexity. It helps toward order, but not toward simplicity. Whenever a new observation is introduced or a new instrument devised, instinctively, as our forebears have done from time immemorial, we turn to see whether it will not give us "a sign." Regretfully, I confess that in my experience the hope has always been disappointed. Take, for ex-

[1] Published, *Quart. Journ. Roy. Meteorological Soc.* Apr., 1919, vol. 45, pp. 95-111. Extracts in *Nature* (London) Aug. 14, 1919, 103: 475-477.

ample, the differences in the times of occurrence of phenomena in the upper air and on the surface; it would be such an easy way of knowing what is coming if changes announced themselves in advance to the aeroplane or the kite balloon, but in most of the cases which I have seen the surface has been the forerunner. You are doubtless aware that a motion of the clouds from the northwest above a southwesterly wind at the surface is a common sign of an advancing depression probably bringing gales; but, rightly read, the omen, the sign of the coming gale, is the southwesterly wind which has already arrived at the surface; the northwesterly wind above it is not a part of things to come—just the reverse—it is the survival of an old depression that has gone by. The backing wind at the surface is the first sign of the coming storm, and it may appear while the pressure is still controlled by the depression that is passing away and which is still most clearly marked by the northwester aloft.

In the present position of meteorological science there are two extremes of opinion—either to think the penetration into the secrets of the subject to be so difficult that we must be content to forego the attempt and deal with what we have, as the Nautical Almanac Office, in vastly more favorable circumstances, deals with the heavenly bodies; or to think it so easy that only observations are required and the training of our brains is of no account. Both these extremes ought to be avoided. Brains without observations are certainly of no avail at all; and observations, however numerous and however widely distributed, will not at this stage of meteorlogical science exonerate us from the use of highly trained intelligence.

So if we would profit by the lessons which this war has taught us regarding the importance of the study of weather we must see to it that the whole scheme of meteorological observation and working is guided by trained intelligence. And if trained intelligence is to be devoted to the important questions which fall within the scope of meteorology there must be money to pay for it at the rates which prevail in the professions with which meteorology must in practice compete.

OFFICIAL APPOINTMENTS AND PROFESSORIAL APPOINTMENTS.

Provision of two kinds is necessary: First, a sufficient number of properly paid professional appointments in connection with the official services to afford the necessary opportunity of a professional career; and secondly, the provision for the necessary training at the universities in mathematics and physics and in meteorological principles and methods. Meteorology, like terrestrial magnetism, geodesics, seismology, and other branches of geophysics, is a graduate study, and it joins on like those to geography and geology, as well as to physics and mathematics. So far as the development of meteorology is concerned, in the matter of training there is and there can be no effective substitute for the professor and his class of students. They have a freedom for making ventures which is denied to public services. What would be regarded as a waste of public money for the professional staff of an office in the pressure of its multifarious duties is a stimulating exercise of the utmost value for a class of students.

Though the profession can not be large enough to form at each of our universities a class of students, all of whom look to the subject for a livelihood, there is no necessity on that ground for having no teachers of professorial rank. The subject is of universal interest and has been so from the dawn of history. That alone, to say nothing of its association with geology and geography, would assure a sufficient audience for a stimulating course of lectures, and with its own appeal and its association with the geophysical subjects there would be no excuse for the highest scientific ambitions of its exponents "to rust unburnished, not to shine in use."

THE SOCIETY: ITS RELATION TO THE GENERAL METEOROLOGICAL ORGANIZATION.

What, then, is the relation of the society to such a future? If I may venture to define it, I would say that the society, as representing all the many-sided interests of meteorological study, may fairly claim the right and duty of fostering, or even of creating, the atmosphere which is necessary for the successful development which is now required.

One of the urgent questions for the future is a new home for its meetings and for its invaluable library. Its journal has enriched the literature of the science with contributions of many different kinds. That, again, is capable of development with great advantage, and in one respect the need for development is extremely urgent. Meteorology is a cooperative science in the progress of which all nations share. Its literature, all told, is probably larger and more diversified in character than that of other sciences. When we take into account the diversity of language and of form, I suppose that there is no meteorologist who can follow for himself without the aid of many colleagues the progress of the science in different parts of the world; and that makes it all the more necessary for the fellows of the society to come to the assistance of each other by providing an effective survey and summary of the work that is being done.

If meteorology is to be put upon a proper footing to discharge its multifarious duties to the public, due provision must be made for the collection of observations to give a proper survey of the rainfall and other aspects of weather for all public purposes.

THE FELLOWS: THE CHANGE IN THEIR POSITION AS OBSERVERS.

Unlike the conditions in the United States, where an official organization took hold of the work of weather observations and compilations, British climatology has grown up from the associated efforts of private individuals, and only this year has passed under official control. This shifting of the control is the cause for some concern as to the direction in which the interests of the increasing number of fellows of the meteorological society can turn.

A fellow of the chemical society, the physical society, or the geological society can make chemical experiments or physical experiments or explore the geology of a locality without engaging other people to make experiments or explorations in other localities at precisely the same time and on precisely the same lines. An astronomer can observe the sun or the moon or any other of the hosts of heaven, and if, alone, he sees something which nobody else has ever observed, or sees it five minutes before another astronomer, great joy is his. With the meteorologist the matter is somehow turned the other way; every observation that he makes is unique and can not be otherwise, and yet its only guaranty of utility is that it will bear comparison with all the rest that have

gone before and with all those made under the same conditions, and at the same time, elsewhere. He is limited by a restricted routine. Official meteorology has very few words of blessing for an observer who exercises his ingenuity in devising new hours of observation, new methods of exposure, new types of common instruments, or new ways of entering observations in the "permanent register." Even improved nomenclature for the forms of clouds is apt to cause indigestion in the official interior. So, with few exceptions, every meteorological enterprise in the way of observation must be the expression of the common purpose of a number of cooperators. The simplest and easiest form of cooperation is the daily recording of a rain gage, and the next in order the daily record of a climatological station with readings once, twice, or three times a day; and the consciousness that science is dependent upon these observations for its material binds the corps of observers together with a feeling of scientific achievement. If the regular supply of observations should no longer rest upon the self-sacrifice of voluntary observers, there is some danger that the light of scientific enterprise will go out of their lives.

OBSERVATIONS ADDITIONAL TO THOSE OF ORDINARY CLIMATOLOGY.

I suppose that we have hardly yet arrived at the time when the voluntary observer can take out his aeroplane for a morning, midday, and evening stroll and get the temperatures and humidity of the upper air up to 15,000 feet as a regular thing. Those who are at all ambitious of scientific achievement might without very serious expense make an effective contribution to the study of the science by including properly tended self-recording instruments in their equipment. A full weather station of the meteorological office now includes a barograph, a thermograph, and a hygrograph. The instruments are easily procured, and except in an atmosphere like that of London they are very durable. In any circumstances their records are of astonishing interest for local purposes and of great importance in the detailed study of weather. The study of the relations of temperature and humidity to the occurrence of fog and frost in different localities is a question of immediate interest. But such instruments are scientific only if scrupulous attention is paid to setting, checking, and timing, duties which require even more skill and care than the daily readings of standard instruments. A new survey of the meteorology of the country on the basis of self-recording instruments is not unworthy of your attention.

With the exception of the sunshine recorder, self-recording instruments other than those which I have mentioned are more difficult for the observer. What an anemometer has to tell us is full of interest, but it is so much dependent upon the exposure that it is not everybody's instrument. We have, for some reason or other, not yet got the recording rain gage which we require, which will tell us truthfully when it rains and when it is not raining. The difference between rain and no rain is very important in meteorology, but a rain gage makes very little of it. It is possible and extraordinarily useful to observe the size and count the number of raindrops or of particles of dust, and to determine the quantity of water in a cloud or the amount of atmospheric pollution in the air. The few determinations of these quantities that are to be found in meteorological literature are not by any means sufficient. There are various electrical instruments, as those for solar radiation and the recording electrometer, of which there are far too few examples in operation. Perhaps the latter is not a very handy instrument in its present form, and something is required which will keep count of electrical fluctuations when thunder clouds are passing over. There is, indeed, a vast field for observations upon atmospheric electricity which is at present unexplored and is open for any one who wishes to be more enterprising than the official establishments, as may be seen by looking into Mr. W. A. D. Rudge's papers before the Royal Society. We may learn from Dr. Leonard Hill that the cooling power of air under specified conditions depending upon wind and evaporation is a very important property of the atmosphere from the hygienic point of view, and can be determined by an instrument which he calls a kata-thermometer, an ordinary thermometer which may be dry or wet and which is raised to the temperature of 100° F. and then exposed. The time which is required for a fall of 5° is read. He promises a rich reward, in the shape of scientific knowledge, for a cooperative study of the atmosphere with this instrument in different localities, and asks for observers who are willing to undertake the duty.

OTHER OPPORTUNITIES OF COOPERATION.

But observing and experimenting are only one side of meteorological activity, and here I should like to say that dealing with observations that have been made requires quite as much scientific skill and daring as devising and making the original observations. From the recollections of my correspondence at the Meteorological Office I feel sure that there are a considerable number of people with scientific aspirations in this country who regard the Meteorological Office as a collection of leisured clerks waiting to be moved to do something by the fortunate originators of bright ideas who flourish most outside, but, so to speak, within striking distance of Government institutions. I do not think I do some of my correspondents injustice if I say that the gist of the correspondence is that if they supply the ideas in the way of the design for an instrument or some original observations in the crude form the Office can do the rest. I can assure them that I have never known the staff of the office to be at a standstill for lack of ideas to carry out, and from the freedom of this chair I will be bold enough to say that there are worse services to meteorology than helping to carry out the ideas of the meteorological office.

THE SOCIETY'S LIBRARY: EPISODES OF METEOROLOGICAL HISTORY.

Let us face the situation: There are 800 of us who are interested in various ways in the study of the weather; and our common duty is, as I have said, to foster or create an atmosphere favorable for the progress of meteorology in the exceptional circumstances now before it. Our medium of communication with each other is the *Quarterly Journal*, which records for our information not only the proceedings at meetings and the papers which are contributed to it, but also the summaries of observations and of work done in various parts of the globe. The material for the advancement of the science even for the most active meteorologist lies mainly in the recorded observations of others which are contained in the library. Let me remind you again that all meteorology is cooperative, and cooperation is not limited to observing. The summarizing of observations is the first step toward utilizing them for scientific purposes, and any one who will help in that way deserves well of the Society. So does any one who will help in

the survey of the meteorological literature of other countries, which forms a large part of our collection.

There is the whole field of the history of meteorology. How little we have done to form a connected story of the study of weather as disclosed by the writings which have come down to us. Men in all ages have been face to face with the problem of the weather. How little do any of us know even of Clement Ley, of Abercromby, of FitzRoy, of Luke Howard, or of Dalton, of Piddington, or Reid, or Capper, or Loomis, or Ferrel, of Hadley, or Halley, or Hooke, or of the still earlier writers on the weather and the early observers before the invention of the barometer and the thermometer? What had the astrologers, who were prepared to forecast everything to say about the weather? Behind all the fantastic explanations which have been discarded there must have been points of view depending upon experience, which may disclose themselves in the writings which survive. What meteorological knowledge had the discoverers of America? What sort of wind blew the Norsemen to Labrador? If I have any knowledge of the feelings of the Society, it would welcome occasional contributions on the history of the science, recent or remote, not less warmly than an account of personal observations. Mr. Bentley has already told us about weather in war, and Mr. Inwards has given us the meteorology of proverb and folklore. Will not some one tell us of meteorology in literature? *Reculer pour mieux sauter* is as apposite to the progress of science as to any other persistent effort, if by it we may understand that an occasional survey of the past helps us to make more sure of the future. Of the 800 of us there must be some who had more leisure and opportunity for retrospective study than the few exponents of meteorology in its modern form, upon whom the Society is accustomed to rely for its subjects of discussion.

THE FELLOW AS A CENTER OF LOCAL INFLUENCE.

And outside the immediate sphere of the Society there is much that is necessary to create an atmosphere favorable for the development of the science. We want people to know that meteorology is not exclusively forecasting. No doubt the view into the unknown future is as Prof. Schuster said in his address to the British Association, the lure of all scientific research, but the long way that has to be traveled in order to make sure of it rewards us with many side views of common human interest. The discovery of the separation of the atmosphere into troposphere and stratosphere surely belongs to the great achievements of the human intellect, and the meteorological exploration of the globe is worth reciting. So I can picture to myself a meteorologist, in some part of the Kingdom or the Empire so remote that he can not share the privileges of our monthly meetings, who would be a center of knowledge of the weather without aspiring to a reputation for foretelling the fortunes of his neighbor's hay or anticipating the prospects of a smooth passage. I admit that it is almost impossible to be the one and avoid the other, largely because meteorology which is not forecasting is a matter of books, maps, pictures, diagrams, and so on. Shortly after the armistice was signed an enterprising film maker wished to make a "movie" of the work of the meteorological office, which he understood had been of great importance in the war. I explained that he might begin with the observer at Spitzbergen or at Madeira and end up with somebody manipulating the receiver of an ordinary telephone; that the intervening parts were telegraph offices, with wires or without, and a person, not in uniform, drawing a map. Finally we came to the conclusion that meteorology would have to be specially dramatized to make a moving picture.

THE AMATEUR'S LIBRARY AND LABORATORY AS A PERMANENT DEMONSTRATION.

So it is with the meteorologist at home—his laboratory is his library, the instruments are books of tables and a slide rule, a drawing board and squared paper or an outline map. He can not even repeat the experiment of forecasting to-morrow's weather until the map comes in, made by somebody else out of other people's observations. But his maps and diagrams when they are drawn are sometimes of arresting interest. And if ever the time should come, as I hope it may, when I have the leisure to please myself as an amateur meteorologist, I for my part, as my duty to the society and for the pleasure of recalling the work of many colleagues, shall make a meteorological laboratory, and I invite other fellows to do the same. It will be mainly books, long rows of books, whose bindings are unimpressive and whose insides are repulsive masses of figures, but they will be in cases with glass doors in the frames of which will be maps and diagrams, photographs of clouds and other pictures expressive of epochs in the study of weather, that tell of notable achievement in a difficult science, that will be sufficiently interesting, in and for themselves, to stifle the almost irrepressible question, "Will it help in forecasting?" and to convey even to the casual visitor the impression that there are many things about the atmosphere that are worth knowing.

I hope that these remarks may appeal particularly to those who are concerned with the teaching of meteorology in schools and colleges, if any colleges there be in which that study finds a place. There are, I know, or there were before the war, many schools in which the practice of observation is taught, and I would like to impress upon them that, while the knowledge of how things are done in practice is important for the learner, it is the knowledge of what things have been done that provides inspiration for the future. The things that have been done in meteorology are not to be found in personal observations, but in books of very special character, which are easily obtained by those who know where to get them, but do not find their way into ordinary libraries. So the material of teaching for meteorology is a collection of special books that wants a classroom as its home and forms a special library. And the knowledge of what has been achieved is best displayed by photographs, maps, and diagrams on a larger scale than is possible in ordinary books, which should have their home on the library walls even if they hide the binding of the books. With these in sight, experience becomes knowledge, and knowledge leads to the desire for more experience.

ATMOSPHERIC PERIODICITIES.

By P. LEVINE.

[Reprinted from *Science Abstracts*, April, 1919, p. 151.]

A curve is drawn showing serial values of the lowest reading of the barometer at Paris for each year from 1700 to 1918, from which it appears that there is a periodicity in this quantity of about 96 years—the curve for 1700 to 1821 being very similar to that for 1796 to 1916.—*R. C.*

VARIABILITY OF TEMPERATURE AND RAINFALL IN BERLIN.

By O. MEISSNER.

[Reprinted from *Science Abstracts*, April, 1919, p. 151.]

A statistical investigation of serial monthly values of temperature and rainfall for Berlin gives the following results: (*a*) The variability of temperature and rainfall of the official Berlin observations, which have been made since 1848 in accordance with approved practice, is normal. (*b*) The amplitudes of the Brückner period and the sun-spot period in this series of observations are so small in comparison with the irregular variations of shorter period, that they require other methods for their determination. (*c*) The old Berlin observations of temperature made by Kirch from 1730 to 1750, when tested by statistical methods, show no reason why they should be regarded as nonhomogeneous. (*d*) The Brückner period of 34 years is well indicated in the temperature observations for August, from 1730 to 1750; in winter the periodicity is quite masked by chance variations.—*R. C[orless]*.

INVESTIGATION OF THE ATMOSPHERIC IN CLOUDY OR THICK WEATHER.

By H. LÖWY.

[Reprinted from *Science Abstracts*, Sect. A, Aug. 30, 1919, Sec. 906.]

The paper describes first of all, methods for obtaining observations of wind-velocity and direction in the upper air by various means which are effective in thick or cloudy weather. One method consists in noting the times of arrival of sounds produced by successive explosions at prearranged intervals at the positions which a free balloon, rising steadily, takes up at those intervals, and deducing therefrom the velocity and direction of the air layers through which it passes. Another is to observe the position at which a shell, fired at a known muzzle velocity and altitude, is seen to emerge from the clouds. Successive shells fired at gradually increasing velocities provide data for the exploration of the wind in successive heights. The computations for both of these methods become very laborious as the height increases, and even for low heights are much more complicated than the corresponding computations for the method of pilot balloons, which can, however, only be used in clear weather. Suggestions are also made for obtaining a record of temperature and pressure at different heights by means of projectiles.—*R. C.*

CHANGE OF ZERO OF THERMOMETERS.

It is well known that thermometers are liable to a "change of zero" with age. In the case of mercury thermometers, the readings become too high, while spirit thermometers read too low. The former effect is explained by a gradual shrinkage of the bulb which naturally forces the mercury up the stem and gives the thermometer a negative correction. For the behavior of spirit thermometers various reasons have been put forward; it has been thought that the thin film of liquid "wetting" the interior of the bore was sufficient to account for the errors found in tests and that standing the thermometer bulb downward for a long while would always get rid of the discrepancies as it certainly does in some cases. The vapor of the spirit has been supposed to enter into chemical combination with the glass or to make its way through it by way of invisible cracks. It seems likely, however, that there is a simpler explanation. As is described in textbooks of physics, mercury thermometers are sealed off when almost filled with mercury, so that they contain practically no air, and as the pressure inside the bulb is less than that outside the strain tends to make it shrink. On the other hand, spirit thermometers are sealed with the bulbs in a freezing mixture, so that they may contain as much air as possible, a condition which is said to reduce the trouble due to evaporation. The result is that such thermometers have high pressure inside the bulbs compared with outside, and therefore there must be a tendency for the bulbs to expand, so that the readings become too low and positive corrections are required.—*F. J. W. W.—Meteorological Office, Circ.* **41**, *Nov. 1, 1919, pp. 3–4.*

NOCTURNAL COOLING OF THE LOWER LAYERS OF THE ATMOSPHERE.

By H. PERROTIN.

[Reprinted from *Science Abstracts*, July, 1919, p. 287.]

According to the equation commonly given in textbooks of meteorology, the temperature θ during the night obeys the law $\theta=\theta_0+Ae^{-\sigma/c.t.}$, where it is supposed that temperature changes are due to radiation only. Here θ_0 is a fixed base temperature, A a constant, σ the so-called coefficient of radiation, c the specific heat of air at constant pressure, and t represents time. On applying this equation to observations made in different parts of the globe, a constant value of σ has been found (about 0.036), which is appreciably higher than the value of the coefficient as determined in the laboratory. According to observations made at Parc St. Maur, Paris, and at three levels (heights 123, 197, and 302 m.) on the Eiffel Tower, from 1890 to 1894, the coefficient varies from 0.033 at the surface to 0.022, 0.018, and 0.016 at the higher levels. It is concluded that the cooling of the lower layers is probably not produced like that of a solid placed in a uniform-temperature inclosure.—*R. C.*

ON THE COOLING OF AIR NEAR THE GROUND AT NIGHT.[1]

By G. HELLMANN.

[Reprinted from *Science Abstracts*, Sect. A, Dec. 31, 1918, § 1221.]

From observations of 10 minimum thermometers, which were arranged at every 5 cm. interval of height above the ground from 5 to 50 cm., the variation of minimum temperature with height is investigated. On clear nights a regular increase of temperature with height is shown, which follows an exponential law. On the average the difference of temperature from the ground to 50 cm. height is 3.7° C. An increase of cloudiness by 1° of the usual scale (0 = clear, 10 = overcast) diminishes this difference by a full third of a degree centigrade. An overcast sky gives no difference of temperature; rainy and windy weather gives a dimimution of temperature of a few tenths of a degree.—*R. C.*

[1] Preuss. Akad. Wiss., Berlin, 1918, **38**: 806-813.

MARTIAN ATMOSPHERE.

[Note from *Scientific American*, Mar. 29, 1919, p. 311.]

On April 11, 1918, Dr. C. M. Olson observed a star pass behind the atmosphere of Mars. "Throughout the star's tangential course its color paled down gradually from brilliance to a very faint salmon tint; at the same time, its disk enhanced in size and softened down to a blurred woolly image, as though overmagnified, or as a small object would appear out of focus."

NOTE ON ÅNGSTRÖM'S PAPER CONCERNING RADIATION AND TEMPERATURE OF SNOW AND THE CONVECTION OF AIR AT ITS SURFACE.[1]

In the May–June, 1919, issue of *Meteorologische Zeitschrift*, pp. 153 to 155, A. Defant has discussed this very interesting paper, which is the result of investigations in Abisko in 1916. It is found that with a clear sky and a temperature difference of 5° C. between the surface and the air above it, the mean temperature of a layer 10 meters thick will be lowered at the rate of ½° C. per minute; further, it is shown that in 24 hours the mean temperature of a layer of air 500 meters thick can be lowered 14° C. This emphasizes strongly the great power of snow in cooling the air, not only in polar regions, but also in the temperate zones.—*C. L. M.*

[1] Anders Ångström: On the radiation and temperature of snow and the convection of air at its surface. Arkiv of Matematik, Astronomi och Fysik, vol. 13, No. 21.

THE "WARMTH OF DAWN".[1]

By O. MEISSNER.

[Reprinted from *Science Abstracts*, Sect. A, Dec. 31, 1918, § 1223.]

From hourly readings of temperature as recorded at the Potsdam Observatory, the conclusion is reached that the difference in point of time between temperature minimum and sunrise has a definite seasonal variation both for clear nights only, and on the average of all nights. From May to September the time of minimum temperature occurs 30 minutes after sunrise; in spring and autumn the interval is reduced to 15 minutes, but in winter minimum temperature occurs 10 minutes earlier than sunrise. Thus there is nothing in the observations to support the "warmth of dawn" theory. —*R. C*[*orless*].

[1] Phys. Zeits., Sept. 1, 1918, 19: 387-388.

PROPAGATION OF HEAT IN THE LOWER LAYERS OF THE ATMOSPHERE.[1]

By H. PERROTIN.

[Reprinted from *Science Abstracts*, Sect. A, Aug. 31, 1918, § 827.]

This is a computation of the quantity (called by G. I. Taylor the "eddy conductivity") which, applied as coefficient of conductivity for the conduction of heat upward from the ground to the upper layers, will produce at those layers the observed values of temperature. An example is worked out for the pair of stations in Paris—Parc St. Maur (at ground level) and the summit of the Eiffel Tower. The eddy conductivity in summer is about 10^6 times the ordinary coefficient of still air as determined in the laboratory.—*R. C.*

[1] Comptes Rendus, May 6, 1918, 166:742-744.

TEMPERATURE MEASUREMENTS ABOUT A WINDBREAK.

By W. SCHMIDT.

[Abstracted from *Meteorologische Zeitschrift*, Sept.–Oct., 1918, pp. 256–257.]

The author has made an interesting study in the exposure of thermometers, and the subsequent effect upon the reading of thermometers on the windward and lee sides of buildings. He used 11 Assmann ventilated thermometers, distributing them on the four sides of the building of the Zentralanstalt für Meteorologie in Vienna. He gives two examples in which there were sudden rises of temperature of 6.4° C. and 4.7° C. on the windward side, whereas those thermometers in the most sheltered and protected positions showed corresponding rises of only 5.5° C. and 4° C., respectively. Other thermometers, variously exposed about the building so as to benefit by eddies, gave readings more nearly in accord with those on the windward side. This effect is one which should be taken into consideration in the exposure of thermometers, especially in view of the customary north-wall exposure of those thermometer shelters which are fastened to windows, whereas warm winds are usually from the south.—*C. L. M.*

CLIMATE OF PALESTINE.

By ELLSWORTH HUNTINGTON.

[Abstracted from "The Future of Palestine," in Geog. Rev., Jan., 1919, vol. 7, p. 31.]

Combined with the scarcity of soil in Palestine, is the great lack of adequate rainfall in summer. Practically all the rain of the year falls between October and May. This means that, wherever possible, irrigation must be practised, as in the Jordan valley, or such crops must be raised as winter wheat, barley, and olives. In the Jordan valley, the warmer half of the year has a mean noon temperature 100° F., and the winter half, 75° F. It can be seen at once that such high temperature results in a general loss of energy. The places where the health is the best are those where the soil is the thinnest and least suited to agriculture. Dry years are another feature of Palestine climate, which hinders agricultural undertakings. In 1909, the author saw thousands of acres of wheat and barley into which sheep and camels had been turned for grazing because there was no crop to reap. Even the drought-resistant olive tree sometimes fails. There are, however, thousands of acres of land which are unplanted and which, if planted with trees would be greatly improved, because they would serve to prevent the too rapid drainage of the water in the soil.—*C. L. M.*

VARIATIONS IN CLIMATE OF ANCIENT PALESTINE.

In a note in the Quarterly Journal of the Royal Meteorological Society,[1] J. W. Gregory comments upon the lack of definite information upon which to base opinions concerning climatic variations in ancient Palestine. It has been said, for example, that the eleventh century B. C. was well watered; but it is here pointed out that that century included David's famine. Similarly, it has been said that the thirteenth century B. C. was dry; but there are the dews on Gideon's fleece and the song of Deborah and Barak to testify as to its wetness. There are also the records of Ruth's famine in the fourteenth century B. C., Elijah's in the tenth, and Elisha's in the ninth, so that there appears to be little ground for definite conclusions regarding periodic variations of climate in ancient Palestine.—*C. L. M.*

[1] Jan., 1919, 45:24.

SIROCCO OBSERVATIONS IN THE SOUTHWESTERN PART OF PALESTINE.

By WALTER GEORGII.

[Abstracted from *Meteorologische Zeitschrift*, July–August, 1919, pp. 193–197.]

The sirocco winds of southwest Palestine find their origin in the desert of Arabia. They are most frequent during the spring and autumn, especially during April and May and September and October. The period during which this very hot wind blows is from one to three days, although it sometimes lasts longer. The normal winds of this region are such that the land and sea breeze are very much in evidence. But when the sirocco sets in from the east or southeast, it is such as to completely neutralize the effect of the sea breeze. The meteorological conditions attendant upon the sirocco were carefully noted from the 12th to the 18th of May, 1916. Table I gives data on temperatures and humidity, for the extreme unpleasantness of the wind is due to the extremely low relative humidity and the sudden rise at the conclusion of the wind.

TABLE I.

Date.	Shelter temperature.			Psychrometer. Dry bulb.			Psychrometer. Wet bulb.			Relative humidity.			Extreme temperatures.	
	7 a.m.	2 p.m.	9 p.m.	7 a.m.	2 p.m.	9 p.m.	7 a.m.	2 p.m.	9 p.m.	7 a.m.	2 p.m.	9 p.m.	Max.	Min.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
May 9	16.2	26.4	16.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	27.5	10.0
10	21.8	26.8	17.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.0	10.2
11	17.4	29.6	18.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.3	13.2
12	19.6	33.6	22.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.5	12.0
13	22.3	35.4	25.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	37.8	15.2
14	29.4	39.5	26.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	39.6	21.2
15	25.2	39.5	28.6	24.6	39.0	26.0	13.0	20.5	14.8	18	12	23	40.1	19.2
16	34.3	40.3	30.0	34.2	41.2	29.0	16.9	17.9	16.2	9	2	20	41.6	23.1
17	35.5	42.0	33.7	35.8	41.0	33.1	16.2	19.0	16.1	2	5	7	43.1	25.0
18	36.1	37.6	22.4	36.2	38.0	22.7	17.0	22.2	21.2	3	20	88	42.1	25.6
19	22.7	25.0	18.0	20.8	25.2	18.1	19.1	20.2	16.5	85	63	85	28.8	20.0
20	18.6	24.9	18.2	18.4	24.4	18.2	16.9	17.8	15.2	86	52	72	26.4	16.5

It will be seen from this table that during the early part of the month of May the temperatures were quite normal, the maximum for the day lay between 26° and 29° C., while the daily minimum lay between 10° and 15° C. On the 11th, however, the maximum reached 30.3° C., which may be regarded as the first symptom of the approach of the sirocco, although in all other respects the day was normal. The sudden rise of temperature during the morning of the 12th, was followed by temperatures which daily mounted higher and higher, until the 17th, the high point of the sirocco, the temperature remained above 30° C. from 5 a. m. until 11 p. m. It will also be noted that the relative humidity during the height of the wind was very low, but that during the 18th it mounted very rapidly. The effect of such low humidity was so marked that a canteen placed for a short time in the wind, in spite of the high temperature, would cool the water within.

Observations of the surface wind and of the wind aloft showed surface wind mainly from the southeast of about 6 meters per second in the middle of the day; aloft, with a southeast wind, velocities as high as 19 meters per second were obtained. The cloudiness during the period is more marked than normal, and consists of higher clouds chiefly, such as cirrus, cirro-stratus, cirro-cumulus, and alto-stratus.

The effect of the sirocco on the human body is especially marked, although the resultant sickness generally comes at the end of the wind. The sudden change of humidity combined with the high temperatures serves to dry the skin rapidly and induce nerve and heart troubles. Recovery from these ills is generally slow.—*C. L. M.*

A HOT "HURRICANE"; THE LEVANTO OF THE CANARIES.

[Reprinted from *The Journal of Geography*, December, 1919, pp. 360–361.]

Study of the wind systems of the world includes reference to a variety of local winds consequent on the cyclonic circulation. The foehn, chinook, sirocco, mistral, bora are all well known from their important human effects. They are described briefly in most textbooks of physical geography while fuller accounts may be found in such meteorological texts as Davis's Elementary Meteorology.

Among the less known winds belonging to this class is the levanto. The levanto, which blows over the Canary Islands as a hot southeasterly wind, may be considered a form of the sirocco. When a well marked cyclonic depression passes to the north of the islands the indraft brings hot, sand-laden air from the Sahara. Occasionally this wind arrives with hurricane force and then is responsible for serious destruction to vegetation and crops. The *African World* (Sept. 20, 1919) describes a recent occurrence of the levanto.

It is to be feared that the tomato and banana industries of the islands have suffered considerably from the levanto or southeast wind which swept down upon the Orotava Valley (north of the peak of Tenerife) in a hurricane of hot air charged with Saharan sand, and more than a suspicion of volcanic gases from the peak. It began to come in hot puffs like a gust from a furnace on the evening of August 22. During the night it attained to the force of a hurricane, and raged all next day and the following night, bursting open shutters and doors, filling the houses with layers of dust, and nearly choking their inmates. Trees came crashing onto roofs, and all vegetation visibly wilted before the scorching blast. Thousands of young tomato plants were killed, the bananas were blackened and rendered unsalable, and the ripe and ripening grapes of the higher slopes simply shriveled and withered. Forest fires broke out spontaneously in several places, adding dense clouds of smoke to the fog of dust.

The intense heat of the wind was doubtless due in part to foehn influence, that is to compression and consequent heating during the rapid descent into the Orotava Valley.

THE BLOWING OF THE WIND.

By ROGER ASCHAN.

A distinguished instructive writer of the sixteenth century, Roger Aschan, was not an aeronautical scientist. The following extract is from *Toxophilus*, a dialogue on the art of archery, published in 1544, and contains references of aerodynamical and meteorological interest. It is interesting to note that the events described occurred on a bright, sunny day, and that the country was comparatively flat.—*Douglas Shaw.*

To see the wind with a man's eyes, it is impossible, the nature of it is so fine and subtle; yet this experience of the wind had I once myself, and that was in the great snow which fell four years ago. I rode in the highway betwixt Topcliff-upon-Swale and Boroughbridge, the way being somewhat trodden afore by wayfaring men; the fields on both sides were plain, and lay almost yard-deep with snow; the night before had been a little frost, so that the snow was hard and crusted above; that morning the sun shone bright and clear, the wind was whistling aloft, and sharp, according to the time of the year; the snow in the highway lay loose and trodden with horse feet, so as the wind blew it took the loose snow with it,

and made it so slide upon the snow in the field, which was hard and crusted by reason of the frost overnight, that thereby I might see very well the whole nature of the wind as it blew that day. And I had a great delight and pleasure to mark it, which maketh me now far better to remember it. Sometime the wind would be not past two yards broad, and so it would carry the snow as far as I could see. Another time the snow would blow over half the field at once. Sometime the snow would tumble softly, bye and bye it would fly wonderful fast. And this I perceived also, that the wind goeth by streams and not whole together. For I should see one stream within a score on me; then the space of two score, no snow would stir, but after so much quantity of ground, another stream of snow, at the same very time, should be carried likewise, but not equally, for the one would stand still, when the other flew apace, and so continue, sometime swiftlier, sometime slowlier, sometime broader, sometime narrower, as far as I could see. Nor it flew not straight, but sometime it crooked this way, sometime that way, and sometime it ran round about in a compass. And sometime the snow would be lift clean from the ground up to the air, and bye and bye it would be all clapt to the ground, as though there had been no wind at all; straightway it would rise and fly again. And that which was the most marvel of all, at one time two drifts of snow flew, the one out of the west into the east, the other out of the north into the east. And I saw two winds, by reason of the snow, the one cross over the other, as it had been two highways. And again, I should hear the wind blow in the air, when nothing was stirred at the ground. And when all was still where I rode, not very far from me more marvel at the nature of the wind than it made me cunning in the knowledge of the wind; but yet thereby I learned perfectly that it is no marvel at all, though men in wind lose their strength in shooting, seeing so many ways the wind is so variable in blowing.—*Aeronautics, London, Dec. 11, 1919, p. 525.*

SPEED OF UPPER WINDS.

[Reprinted from *Aeronautics* (London), Jan. 15, 1920, p. 68.]

The pilot balloons which are sent up daily to record the movements of the atmosphere at various altitudes showed on January 9 that, in the upper air, the wind was traveling southeast at a phenomenal speed. At 16,000 feet its velocity was from 70 to 80 miles an hour; at 26,000 feet the wind was moving at the astonishing speed of 180 miles an hour. The Airco service at a comparatively low altitude found that, even over the Channel, where as a rule the winds are strongest, the velocity was not more than from 40 to 50 miles an hour.

SOUTHERN HEMISPHERE DECADAL AND MEAN MONTHLY ANNUAL RAINFALL.[1]

By R. C. MOSSMAN.

[Abstract.]

In studies relating to agriculture it is often desirable to compare the seasonal or monthly rainfall distribution in different regions so as to be able to form some idea of the suitability of a given locality for the cultivation of a crop not hitherto grown in that district, due regard, of course, given to such factors as temperature, sunshine, soil, and exposure. Comparisons of this nature are often affected by taking such monthly or annual normals as are available, without reference either to the length of the period embraced by the records, or the synchronism of the data. * * *. As a first step toward uniformity in the matter of Southern Hemisphere rainfall, the decadal and, generally, monthly and annual means given in the tables appended [not reprinted here] have been computed. The records are mainly from the western seaboards of South America, New Zealand, and Australia. It is hoped from the large mass of temperature, pressure, and other data available to compute decadal means for the other elements of climate, since even a superficial examination of the rainfall normals here given shows several directions in which interesting research could in this way be undertaken.—*H. L.*

[1] Quart. Journ. Roy. Meteorological Soc., Oct., 1919, vol. 45, pp. 355-366.

A NEW METHOD FOR DETERMINING TOTAL RAINFALL ON THE OCEANS.

By FRITZ VON KERNER.

[Abstracted from *Meteorologische Zeitschrift*, May-June, 1919, pp. 167-168.]

Investigations by Schmidt and Lütgens on the total rainfall over the oceans have given quite discordant results (242,000 and 475,000 km.^{3}), while Brückner's value (360,000 km.^{3}) is about the average of the first two. These investigations were made upon the study of evaporation. The present investigation, however, used as its basis, the known rainfall data for the Indian Ocean and the North Atlantic. These were arranged according to latitude, together with the surface salinity of the ocean. By rearranging the data, the rainfall values were plotted against the surface salinity of the ocean. Knowing the salinity of the surface of other oceans, it is reasonable to assume that the relation between salt content and rainfall hold there also, thus giving a basis for computing the total rainfall for the entire water area. A careful computation yields for the annual rainfall over the water surface of the earth, a value of 360,500 cubic kilometers, which is in very good agreement with the value determined by Brückner upon the basis of evaporation.—*C. L. M.*

JAPANESE BUSINESS MEN BUILD MARINE METEROLOGICAL OBSERVATORY.

The construction of a marine meteorological observatory which is now going on at Kobe is expected to be completed and opened to service in March. The building of the observatory owes its origin to the contribution by Kobe business men of 230,000 yen for the purpose, and an estimate of 150,000 yen will be introduced in the forthcoming session of the Diet for wireless installation. [An additional 400,000 yen may be appropriated to extend the sending radius to ships as far as Hongkong.].—*U. S. Naval attaché at Tokyo.*

WINTER SEVERITY AS A CLIMATIC FACTOR.

By OTTO BASCHIN.

[Abstracted from *Das Wetter*, July-August, 1918, pp. 101-104.]

It is commonly noted that cold seems more severe when it is accompanied by a strong wind. This led Vincent, in 1890, to develop an equation expressing a relation between H, the skin temperature, L, the air temperature, S, the difference between the temperature in the sunshine and in the shade, and V, the wind speed, as follows:

$$H = 26.5 + 0.3L + 0.2S - 1.2V.$$

From this equation he obtained the limits of the sensation of "very hot" and "very cold." That is, when H was greater than 37.5° C. it was considered "very hot," and when less than 22° C. it was considered "very cold."

Later G. Bodmann expressed an index of weather severity as a function of air temperature and wind velocity, as follows:

$$S = (1 - 0.4t)(1 + 0.272v),$$

in which S is the index of severity, t the temperature, and v the wind velocity. A table, giving the values of t and v corresponding to various values of S, is presented together with another showing the values of S, t, and v, for various localities during the time of severest weather. The author points out that not enough attention has been given this matter by climatologists, and points to the brief and "easily misunderstood" reference in Hann's *Handbuch der Klimatologie* and the brief tables of "mean temperatures" and "mean wind speed."—*C. L. M.*

MOUNT KÉNYA: NOTES ON THE GEOGRAPHY OF AN EQUATORIAL SNOW PEAK.

[Reprinted from *Geographical Review*, New York, Oct., 1918, pp. 372-373.]

There are considerable differences in zonal distribution between the eastern and western sides of the mountain, especially in the lower forest zone, which is economically the most important. On the west the forest begins at an elevation of 7,000 to 7,500 feet. For the northwest Alluaud and Jeannel place it as high as 7,870 feet.[1] On the southeast the lower edge of the forest begins about 6,000 feet. Here it is much denser, and the place of the distinctive juniper (cedar) of the west is taken by great camphor trees. The drier west appears to have suffered greatly from fire, and the higher altitude at which the forest begins may be due in part at least to the destructive grazing fires of the Masai. Evidently precipitation is the dominant factor controlling the differences of the vegetational zones. Kénya is exposed to prevailing easterly winds (southeast trade, northeast monsoon). Hutchins estimated that, where the rainfall of the southeastern slope was 80 to 120 inches a year, that of the west was 50 to 90 inches.

The most recent observations on Kénya by Capt. G. St. J. Orde Brown[2] emphasize the extreme humidity of the mountain, a fact which explains the low limit of snow (about 14,500 feet on the southeast), as von Höhnel, Teleki's companion, comments, lower than that of Kilimanjaro.[3] For at least nine months of the year Kénya is "covered with mist, varied by heavy rain;" in fact the only months when finer weather can be depended on are February and early March. A marked consequence of the heavy rainfall is seen in the high degree to which the south-eastern face is eroded, the gorges being cut much more deeply than on the other sides. * * *."

[1] Le Mont Kénya en Afrique Orientale Anglaise, Rev. Gén. des Sci., July 15, 1914, pp. 639-644.

[2] The Southeast Face of Mount Kénya, Georg. Journ., June, 1918, pp. 389-392.

[3] Ostäquatorial-Afrika, zwischen Pangani und dem neuentdeckten Rudolph-See, Ergänzungsheft zu Petermanns Mitt. No. 99, 1890.

THE GEOGRAPHICAL BARRIERS TO THE DISTRIBUTION OF BIG GAME ANIMALS IN AFRICA.

By EDMUND HELLER, Naturalist.

[Author's summary, *Geographical Review*, October, 1918, p. 319.]

It is climate that exerts the chief control over the distribution of animals in equatorial Africa. The five zones which we have here employed in defining the ranges of game animals and native tribes have been established on a climatic basis. Coincident with climate are distinctions of flora on which the animals are dependent for food and protection. Temperature first and then moisture are the most important climatic elements. Temperature is dependent chiefly on altitude, and our zones, inasmuch as they are primarily defined by temperature, have very definite altitudinal boundaries and lie one above another. In accord with the banded orographical structure of the region we find the life zones disposed in ribbonlike arrangement and paralleling the coast in a general way the whole length of the eastern side of the continent. Summarizing the five life zones briefly, we have first the narrow coast zone rising from sea level to 500 feet or so. Above this the great desert, or nyika, zone extends from 500 feet to an altitude of 3,000 feet. Above the desert the highland veld rises from 3,000 to 8,000 feet, its altitude giving it a cooler and moister climate. Rising still higher above the plateau there is a highland forest area on mountain slopes and summits covering the altitudes between 8,000 to 11,000 feet, where the climate is decidedly moister and cooler. The area lying above the tree zone, which is alpine in the character of its plant growth and climate, is infinitesimal in Africa in comparison with the other zones. In Uganda we have an area or zone, the tropical forest, which is dependent on soil conditions rather than altitude. Here we find a dense tropical forest covering certain areas within a grass veld region. To some extent this area is artificial, the grass veld having been extended by native agricultural methods at the expense of the forest area. Within these zones are two important river barriers, the Nile and the Tana, which subdivide the nyika zone, as their waters form important barriers to big game mammals. As a barrier these rivers are here only of great importance to the distribution of big game, smaller mammals being much less affected. Reptiles, birds, other animals, and vegetation are scarcely affected at all by these rivers in their distribution, though they are subject to the zonal or climatic barriers quite as much as are big game mammals. There is no region in the world where large mammals have been so limited in their distribution by rivers as in equatorial Africa.

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SOLAR AND SKY RADIATION MEASUREMENTS DURING JANUARY, 1920.

By H. H. KIMBALL.

[Pending a decision as to an appropriate reduced form in which to present these data, publication will be delayed.]

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Director.

[Dated: Astrophysical Observatory, Smithsonian Institution, Washington, Feb. 14, 1920.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in December, 1919, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

A special feature of the December values is their general high level and their rise to an uncommonly high maximum near the end of the month. This is interesting in connection with the generally low temperature in the eastern part of the United States.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρ s.c.	V. P.	Relative humidity.	
1919. P. M.	cal.					cm.	%	
Dec. 1	1.955	M_2	S	0.854	0.621	0.27	11	Cirri scattered about sky.
	1.958	$M_{1.41}$						
	1.957	W. M.						
3	1.960	M_2	S	.847	.615	.38	16	Cirri scattered over much of sky, but gradually disappearing.
	1.959	$M_{1.5}$						
	1.950	$M_{1.06}$						
	1.958	W. M.						
A. M. 5	1.958	E_0	E—	.849	.472	.27	24	Some thin scattered cirri in east, north, and west, gradually disappearing.
	1.959	M_3						
	1.959	M_2						
	1.944	$M_{1.5}$						
	1.950	W. M.						
6	1.948	M_3	S—	.819	.409	.34	23	Cirri in east and some scattered about rest of sky.
	1.939	$M_{1.5}$						
	1.943	W. M.						
7	1.934	$M_{1.42}$	S—	.826	.479	.36	26	Cirri in southwest and scattered thinly about rest of sky.
8	1.944	M_2	S+	.833	.447	.45	32	Cirri in east, west, and south.
	1.944	$M_{1.5}$						
	1.944	W. M.						
9	1.965	$M_{1.27}$	U+	.852	.618	.48	31	Cirri in all parts of sky.
P. M. 10	1.947	M_2	S—	.836	.483	.41	19	Cirri in east, but clearing in west.
	1.959	$M_{1.60}$						
	1.955	W. M.						
A. M. 12	1.926	E_0	VG+	.848	.415	.42	41	Distant cirri in north, east, and west.
	1.972	M_3						
	1.969	M_2						
	1.953	$M_{1.43}$						
	1.957	W. M.						
1919. A. M.	cal.					cm.	%	
Dec. 15	1.944	$M_{1.5}$	S—	.815	.361	.63	42	Cirri over sky.
	1.964	$M_{1.69}$						
	1.951	W. M.						
16	1.945	$M_{1.06}$	S—	.827	.433	.80	46	Cirrocumuli scattered over most of sky.
17	1.940	E_0	G	.816	.269	.67	55	Cirri in north and east, some cumuli in south.
	1.994	M_2						
	2.006	$M_{2.52}$						
	1.941	$M_{1.26}$						
	1.965	W. M.						
18	2.009	M_2	S—	.829	.332	.65	46	Cirri in east and north, moving south.
	1.973	$M_{1.5}$						
	1.985	W. M.						
19	1.967	$M_{1.5}$	S—	.839	.477	.70	30	Thin cirri over much of sky, especially in north and east. Distant cumuli in east.
	1.945	$M_{1.14}$						
	1.960	W. M.						
20	1.948	$M_{1.11}$	S—	.839	.570	.53	28	Cirri scattered about sky.
21	1.948	$M_{1.25}$	S—	.840	.563	.38	22	Very thin cirri over much of sky.
22	1.959	E_0	VG+	.828	.364	.40	38	Cirri in northeast.
	1.988	M_3						
	1.977	M_2						
	1.963	$M_{1.5}$						
	1.969	W. M.						
23	1.967	E_0	E—	.817	.330	.38	34	
	1.986	M_3						
	1.970	M_2						
	1.954	$M_{1.5}$						
	1.967	W. M.						
24	1.932	E_0	VG—	.856	.363	.38	34	
	1.997	M_3						
	1.975	M_2						
	1.976	$M_{1.5}$						
	1.972	W. M.						
25	2.006	M_2	U+	.824	.362	.49	37	Some cumuli in east.
	1.964	$M_{1.5}$						
	1.978	W. M.						
26	1.987	E_0	VG	.802	.253	.54	56	Cirrocumuli low in east.
27	1.807	E_0	P	.812	.218	.65	69	Cirrocumuli in north and east, and some cirri in south.
28	2.008	M_2	U+	.822	.314	.65	46	Cumuli along horizon in east.
	1.981	$M_{1.5}$						
	1.994	W. M.						
29	1.964	$M_{1.19}$	U+	.826	.442	.78	43	Scattered cirri and cumuli over most of sky.
31	1.964	E_0	G	.830	.304	.61	53	Cirrocumuli scattered over much of sky.
	2.002	M_2						
	1.975	$M_{1.5}$						
	1.979	W. M.						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By H. C. FRANKENFIELD, Supervising Forecaster.

Midway Islands and Honolulu.—The former showed high pressures for the season in the first decade and below normal pressures thereafter, while Honolulu was continuously low the entire month, the markedly low reading of 29.64 inches being reported on the 17th.

Alaska.—Pressure was low during the first week of the month and decidedly and continuously high thereafter, while temperatures were just the reverse, being above normal during the first week followed by below normal temperatures to the end of the month.

United States.—Pressure alternated between low and high during the first and second decades, except in the Rocky Mountain Region where it was high, while during the last decade it was for the most part almost continuously above normal throughout the entire country.

Azores and Bermuda.—Pressure at Bermuda was low from the 3d to 6th and 12th to 16th, and high from the 7th to 10th and from 19th to the end of the month, while Horta was high from the 1st to 11th and 15th to 24th, low from the 12th to 14th, and indifferent from the 25th to 31st.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY, Meteorologist.

January weather on the North Pacific Ocean was, on the whole, similar to that of December, during which relatively quiet conditions prevailed.

From the 1st to the 7th a well-developed cyclone occupied the region of the Aleutian Islands, Bering Sea, and Alaska, with anticyclones extending along both the North American and Asiatic coasts. This pressure distribution resulted in moderately strong westerly winds along the northern steamer routes, at times reaching the force of a fresh gale. Continuous strong southerly winds prevailed along the coast of southeastern Alaska.

Commencing about the 8th, the Asiatic anticyclone developed progressively to the eastward, while pressure rose strongly over Alaska. The Pacific coast anticyclone diminished and moved southeastward. This rearrangement of pressure left the eastern Pacific covered by a cyclone of considerable magnitude but only moderate intensity and with low pressure developing in the region of the Japanese Islands. This pressure distribution continued with but slight modifications until the end of the month.

On the 12th and 13th strong gales were experienced along the northern steamer route near the one hundred and fiftieth meridian and moderate gales on the southern route east of the Hawaiian Islands. On the 23d and 24th moderate gales again prevailed on the latter route and also to the eastward of Japan.

NORTH AMERICA.

By H. C. FRANKENFIELD, Supervising Forecaster.

During the early part of the month with high pressure over the northern and central Plateau regions and low pressure over Alaska, low areas made their appearance over Alberta and as is more or less common with LOWS of this type gave birth to several secondaries, and, while several secondary high pressure centers broke off from the Plateau HIGH and moved eastward, the Alberta type of anticyclone was almost entirely absent. These conditions resulted in extremely cold weather in the West and South, especially in the latter, and in fairly general precipitation from the Plains States eastward, with snows in northern and rains in southern districts.

In the latter part of the month, with continuously high pressure in Alaska, Alberta LOWS were infrequent, the only LOW of North Pacific origin that developed during the month and high pressure areas of the Alberta type, accompanied by quite low temperatures, advanced eastward and southeastward from that region. During the last decade, although well-defined low pressure areas were rare, precipitation was more or less frequent from the Mississippi Valley eastward and an ice storm occurred in the Ohio Valley, Tennessee, and in the mountain districts of southwestern Pennsylvania, Virginia, and the Carolinas (see p. 50, below).

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was slightly above the normal at land stations on the American coast, in the West Indies, the Bermudas, and the Azores, while it was considerably below on the north coast of Scotland.

As in the previous month the average pressure gradient between the Azores HIGH and the Icelandic LOW was abnormally steep, with unusually heavy weather over the eastern section of the steamer lanes.

The LOW that was central off the Canadian coast on December 31, 1919, as shown on Chart XVI for that date moved rapidly eastward, and on January 1 was central near latitude 52° N., longitude 37° W. (see Chart IX). Heavy southwesterly gales swept over the region between the fortieth and fiftieth parallels, and thirtieth and fiftieth meridians, several vessels reporting wind velocities of from 75 to 90 miles an hour. On the same day strong northerly gales were encountered as far west as the twentieth meridian. On January 2, as shown on Chart X, the western disturbance of January 1 was central near latitude 50°, longitude 22°, while winds of from gale to hurricane force prevailed between the twentieth and fortieth meridians.

On the 3d the center of this LOW was near Valentia, Ireland, and the storm area had contracted in extent since the previous day, although northwesterly gales, with hail, were still encountered in the southwesterly quadrants. On the 5th a disturbance of limited extent was central near Bermuda, with northerly gales between the thirtieth and fortieth parallels, west of the sixty-fifth meridian. From the eighth to the twelfth moderate to strong gales were encountered over the eastern portion of the steamer lanes, reaching their maximum intensity on the 11th, when a number of vessels off the Irish coast reported wind velocities of over 60 miles an hour. Chart XI for January 13 shows a LOW central about 300 miles east of St. Johns, N. F., with strong gales in the southerly quadrants, extending as far south as the thirty-fifth parallel. On the 14th (see Chart XII) heavy weather

prevailed over the greater part of the steamer lanes, as well as over the region between the thirty-fifth and fortieth parallels, and the fiftieth meridian and the European coast. By the 15th the weather had moderated over the northern waters, while in the southern area heavy winds continued until the 21st. The observer on board the American steamship *West Harshaw* reported in a communication regarding this gale as follows: "In conjunction with the gale of January 14 and 15, there was a low lying fog caused by the cold air coming in contact with the warm water. The sea was steaming. At times fog extended over 75 feet in the air and came in gushes, but usually during a squall of cold wind it hung near the water." The position of the vessel at Greenwich mean noon on the 14th was given as latitude 35° 57′ N., longitude 66° 40′ W., and on the 15th, 36° 37′ N., 66° 40′ W. From the 21st to the 23d strong southwesterly to northwesterly gales prevailed over the mid-section of the steamer lanes, with hail and snow on the latter date. On the 24th and 25th the storm area extended over nearly all the ocean north of the fortieth parallel, although on the latter date there was an area of moderate winds between the forty-fifth and and fiftieth parallels and twentieth and thirty-fifth merdians. On the 27th there was a well developed LOW off the west coast of Ireland, with a minimum barometric reading of 28.73 inches; strong westerly gales swept the region between the twentieth meridian and the European coast, while fog was reported in the Irish Channel. From the 29th to the 31st vessels on the eastern section of the steamer lanes encountered moderate westerly and southwesterly gales, and on the latter date the storm area extended over practically the entire ocean, north of the fortieth parallel.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Mexico.—Mexico City, January 28.—A cold wave of unusual intensity is prevailing here. Forty deaths have been caused among the poorer classes in Mexico City by the cold, and it is feared that the crops in the northern States have suffered damage.—*Washington Evening Star.*

British Isles.—Except for a brief cold spell about the 6th and 7th, weather of an oceanic or southwesterly type prevailed during the greater part of the month. Depressions, which were often of great size and intensity, followed one another in rapid succession and very commonly traveled on a northeasterly course, so that the winds from westerly or southwesterly points predominated, with the result that there were many mild days and the mean maximum temperature for the month in some parts of England exceeded the normal for January by about 4° F. Comparatively high temperatures extended as far as the Arctic Circle, the thermometer at Spitzbergen standing at about 36° F. for a few days. Gales were frequent and widespread, and at times the speed of the wind was very great. [A gust exceeding 50 meters per second. (over 110 miles per hour) was recorded at Quilty, Ireland, Jan. 27.]—*The Meteorological Magazine, February, 1920, pp. 7, 11, and 16.*

For the nine weeks of winter from November 30 to the end of January there was an excess of temperature, and also of rainfall over the British Isles. The controlling factor was the frequent passage of disturbances from the Atlantic, the centers of which for the most part traveled in proximity to Scotland.—*Nature, Feb. 12, 1920, p. 639.*

France.—The chief feature of January, 1920, has been its storminess and the exceptionally heavy rainfall in western and central Europe. * * * Paris suffered considerable damage, the Seine at Pont Royal reaching a level of 24 feet 3 inches above the normal—the highest ever reported. River traffic was impossible, the bridges being blocked. The Seine began to fall on January 5, but a state of flood was maintained more or less through the month.—*The Meteorological Magazine, February, 1920, p. 16.*

Paris, January 5.—In Paris and the suburbs 22,000 persons are idle because of the flooded factories. Thirty-one suburbs are inundated and 7 miles of foot bridges have been constructed. * * * There is little news from the Provinces, but the reports confirm previous advices respecting the widespread flooding of farms and villages.—*Washington Post, Jan. 6, 1920.*

Germany.—Coblenz, January 16.—Flood waters in the Rhine and Moselle Rivers here have reached the highest stage in 136 years, according to official German records. * * * Reports from higher up both streams state that the rain has ceased, and it is expected, with the anticipated advent of cold weather, that the water will soon recede.—*N. Y. Evening Post, Jan. 17, 1920.*

Bohemia and Moravia.—[In the middle of the month] heavy floods were experienced on the rivers of Bohemia and Moravia.

Hungary.—On the 17th and 18th the Danube inundated the lower streets of Budapest.—*The Meteorological Magazine, February, 1920, p. 16.*

Russia.—Reval, January 10.—Thousands were frozen to death in a blizzard which swept across Esthonia on New Year's Day. Reports received here state that 300 bodies of refugees were found in a forest between this city and Narva, and American Red Cross workers say many babies were frozen to death at their mothers' breasts.

Many fugitives from the collapsed army, led by Gen. Yudenitch in his recent offensive against Pertrograd, have perished in the drifting snow.—*Washington Evening Star, Jan. 10, 1920.*

Italy.—Rome, January 8.—Heavy rains are causing floods throughout most of Italy. The Arno and Tiber Rivers are overflowing their banks and inundating many sections. In several districts houses have collapsed.

Later in the month [11th to 17th] the Arno, at Florence, was in flood, and at the same time heavy rain and mild weather in the Alps, following on a heavy snowfall, caused destructive avalanches.—*The Meteorological Magazine, February, 1920, p. 16.*

Australia.—Clippings from the Mercury, Hobart, Tasmania, and notes in the Meteorological Magazine (February, 1920, p. 16) indicate that the great drought which has menaced Australia was ended over much of the stricken region during the last few days of November and the first days in December by heavy falls of rain in eastern New South Wales and Victoria, which substituted floods for the drought. There was more rain late in December and useful rains occurred throughout January.

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By R. HANSON WEIGHTMAN, Meteorologist.

Cyclones.—Chart II shows tracks of 8 primary and 4 secondary lows distributed by regions of origin as indicated below. Low No. VIII has been included with the Alberta lows, although outside the limits of that region as shown on Chart I, MO. WEA. REV., SUPPLEMENT No. 1. Low No. III–B is not included in the table.

	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
January, 1920	7.0	1.0	0.0	0.0	1.0	......	......	1.0	1.0	11.0
Average number, 1892–1912	4.7	2.5	0.9	0.4	1.4	1.5	0.4	0.4	0.5	12.7

The month is somewhat remarkable in that only one center passed through the Gulf States and that, with the exception of low No. II–B, the centers of disturbances kept well to the northward.

Anticyclones.—On Chart III are set out the tracks of 11 primary highs and 4 secondary highs or offshoots of the types indicated below.

	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
January, 1920	0.0	1.0	10.0	4.0	0.0	15.0
Average number, 1892–1912	0.8	0.6	5.5	1.7	0.4	9.0

The most important features were the persistence of high pressure over the northern and central Plateau regions from about the 7th to 18th or 19th, inclusive, and the abnormally high pressures recorded in connecting with high No. XI and high No. IX.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Mar. 1, 1920.]

PRESSURE AND WINDS.

At the beginning of the year high pressure existed in the Plains region and a cold wave had advanced to the central valleys, while over the more eastern districts a low pressure area was moving over New England accompanied by light snow from the Great Lakes to New England, and by local rains in the Southeast. In the far West the weather was generally clear with continued cold in the Plateau region.

High pressure and severe cold prevailed over central and eastern districts until after the middle of the first decade and the coldest weather of the month was recorded during this period over the east Gulf and South Atlantic States. Minimum temperatures from 5° to 10° below zero F. were observed as far south as Tennessee and North Carolina, and they were below freezing in all States to the southward, except along the immediate Gulf and Atlantic coasts and over portions of the Florida Peninsula. During the same period cold weather continued in the far West. The latter part of the decade had somewhat lower pressure in the central and eastern districts, with very general precipitation from the Plains region eastward, snow occurring over the northern, rain or snow over the central, and rain over southern districts, the rainfall being generally heavy from the Mississippi Valley northeastward to the headwaters of the Ohio. During this period high pressure continued in the far West and temperatures remained generally below the normal.

The first half of the second decade was without marked pressure variations although the barometer continued high in the Plateau region and moderately low along the northern border. By the middle of the decade low pressure had developed in the Plains region and during the following two days it moved into the central valleys and eastern districts, snow occurring quite generally from the Dakotas and Iowa eastward, and rain to the southward of the Ohio and along the Middle Atlantic coast. The latter part of the decade had generally high pressure in the central plateau, but along the northern border and generally over the central and eastern districts the pressure was comparatively low, particularly near the end when stormy conditions with more or less snow prevailed along the northern border from the Rocky Mountains to New England, extending southward during the early days of the last decade, at which time light snows occurred over many northern sections and rain was general to the southward, particularly about the 23d and 24th, when heavy falls occurred over extensive areas from Texas northeastward to the lower Ohio Valley. At the same time high pressure prevailed over the northern districts rising above 31 inches in eastern Montana, attended by the severest cold of the month. This high area moved along the northern border but its influence was felt far to the southward, freezing temperatures being experienced as far south as the Gulf coast. This was generally followed by lower pressure in the far northwest, accompanied by much warmer weather, and the highest temperatures of the month were recorded about this time over a large area from the upper Mississippi Valley westward.

During the latter part of the decade high pressure again prevailed over the northern districts, particularly on the 30th, when it became unusally high to the northward of the Dakotas attended by severe cold. At the end of the month this high pressure area covered the northeastern States and some of the highest barometer readings ever observed in that region were reported.

The average pressures for the month were above 30 inches and also above normal in all portions of the United States and likewise in Canada as far north as observations disclose.

The distribution of pressure during the month, particularly the prevalence of high areas along the northern border, favored winds with a northerly component over much of the country from the Great Plains eastward. Over the far western district the prevailing winds were likewise mostly from northerly points except from Montana westward, where they were frequently from the south. Severe winds were rather infrequent although they occurred very generally along the North Atlantic coast on the 14th and again on the 17th and 18th.

TEMPERATURE.

The month was decidedly cold as a whole from the Great Lakes eastward to New England, the daily values in portions of this area remaining below normal nearly the entire month. The periods of greatest cold were during the first few days of the month over nearly all southern sections from Texas eastward and south of the Ohio River; about the 8th to 10th from Texas and Oklahoma westward including the greater part of the region from the Rocky Mountains to the Pacific; about the 24th to 25th from the Great Lakes and Ohio Valley westward to the northern Rocky Mountains; and at the end of the month over the northeastern States. At Burlington, Vt., the minimum temperature slightly after midnight of the 31st, $-28°$, was the lowest ever reported at that station.

The highest temperatures were generally observed during the last decade of the month although along the Pacific coast they occurred on the 16th and 17th when local maximum values were higher than any previously observed in January. Over the southern States to eastward of the Mississippi some unusually high temperatures for January were observed on the 23d and 24th.

The monthly means were well below normal from the upper Mississippi Valley eastward to the Atlantic coast, the deficiencies ranging from 8° to 12° over the Great Lakes and the northern portions of New York and New England. Mean temperatures were also below normal over a limited area in western Colorado and eastern Utah, where severe cold persisted throughout the month, despite the fact that nearby localities on all sides had temperatures above the normal. At Grand Junction, Colo., the temperature was below the normal on all except five days of the month, and from October 1, 1919, to January 31, 1920, a period of 123 days, only 23 days have been warmer than the average.

With the exception of the area referred to above, practically all portions of the country from the Great Plains westward had monthly mean temperatures above the normal, and from Arkansas and Louisiana eastward all southern States likewise had averages above the normal.

PRECIPITATION.

The month was generally far less stormy than is usual for midwinter, and large portions of the central valleys and Northwest were almost entirely free from severe storms.

The principal periods of precipitation were during the middle and latter parts of the first decade when some unusually heavy rains for winter occurred in Arizona and heavy rains prevailed from central Texas northeastward to the Ohio Valley, with more or less rain or snow over most other central and eastern districts; about the middle of the second decade, when snows and rains were general from the Mississippi River eastward; and again in the middle of the third decade, when precipitation was general and in some cases heavy in the Gulf and Atlantic coast States, and more or less rain or snow occurred over other districts from the Great Plains eastward.

For the month as a whole the precipitation was greater than normal throughout the Gulf region, except in portions of Florida, the southern drainage area of the Ohio River, and over portions of the northern Plains, and southern Mountain districts. Throughout the other sections of the country the falls were generally less than normal, particularly over the Pacific Coast States.

In California the rainfall as a whole was the least for January in the history of the State, and this is accentuated by a general shortage in precipitation for each of the preceding four months, and further that the past three years have also had deficient precipitation. As a result the reservoirs at the end of the month were being rapidly emptied, the streams were at usually low stages, and the ground water had receded to the lowest known levels. In view of the paramount importance of an adequate supply of water for agricultural and power purposes, peculiar to that State, the present depletion of the water supply at a period when it is normally at the maximum, is cause for serious fears that disastrous results face the interests of the State during the coming summer.

SNOWFALL.

During the early part of the month some snow fell locally in the Lake region and in the mountain districts of Utah and Colorado, and the snow cover was increased slightly in a few places, but only very light falls occurred in the high mountains of California and the far Northwest. Toward the middle of the month light snows fell in portions of the western mountain districts, while there were moderate falls in the northern States from the Dakotas to New England and from the Ohio Valley eastward.

During the latter half of the month rather frequent light snows fell in the northern districts from the Mississippi Valley eastward, and a rather extensive snow, sleet, and ice storm moved over much of the country from the Ohio and Tennessee Valleys to the Atlantic. The heavy ice coating greatly interfered with traffic and caused damage to overhead wires, orchards, and shrubbery. In the western mountains there was but little snow during this period save in portions of Montana and a few points in Idaho and Colorado.

For the month as a whole there was a general decrease in the snow cover over all portions of the country, it being less at the end of the month than at any time since the beginning of the winter. The absence of any material additions during January to the stock of snow in the mountains of the far West continues to cause apprehension regarding the water supply, notably in California, where the cover is unprecedently light for the period of the year.

RELATIVE HUMIDITY.

In central California and portions of Nevada the relative humidity was far less than normal, and locally in the northern Rocky Mountain States, the Great Lakes, and Appalachian region and along the Atlantic seaboard the relative humidity was likewise generally below the seasonal average. Throughout most of the remaining sections of the country there was relatively more moisture in the atmosphere than is usual for January, although the departures from normal were small, except in portions of the southern Plains and Mountain regions, where they were unusually large.

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Weather Bureau, Feb. 16, 1920.]

STORM WARNINGS.

On the morning of January 1 there was a disturbance of marked intensity over the upper St. Lawrence Valley, moving northeastward, so at 12 noon NW. storm warnings were ordered along the Atlantic coast from the Virginia Capes to Eastport, Me. However, a lagging behind of the western section of the low pressure area lessened the storm intensity, and, except between New York City and Block Island, R. I., there were no strong winds until during the night of the 2d–3d, when there were moderate westerly gales between Cape Henry, Va., and Block Island.

On the morning of the 6th a moderate disturbance was developing off the western coast of the Gulf of Mexico, with an extensive and marked high pressure area to the eastward, so at 10:30 a. m., SE. storm warnings were ordered along the east Gulf coast from Bay St. Louis, Miss., to Carrabelle, Fla., strong E. and SE. winds being forecast for the day and night of the 6th. Strong SE. winds occurred as forecast.

On the evening of the 7th a southern plateau LOW was central over the mouth of the Rio Grande, with a northeastward movement, so at 10:30 p. m. SE. storm warnings were again ordered from Bay St. Louis to Carrabelle. Moderately strong winds followed.

By the morning of the 9th the center of the disturbance had reached the upper Ohio Valley with increased intensity, and at 3 p. m. warnings were ordered along the Atlantic coast from Point Judith, R. I., to Provincetown, Mass., for strong NE. to NW. winds at night and NW. on on the following day. Moderately strong NE. winds followed, and the warnings were lowered on the morning of the 10th. On the morning of the 12th a LOW from the far NW. was over Manitoba in marked form, so at 10 a. m. warnings were sent to open ports on Lake Michigan for strong SW. to W. winds with snow and rain, shifting to NW. on the 13th. This warning was fully justified. By the evening of the 12th the center of the disturbance was over northern Lake Superior with undiminished intensity, and at 10:30 p. m. SW. storm warnings were ordered along the Atlantic coast from Delaware Breakwater, Del., to Bangor, Me., for strong SW. winds with snow by the following evening. Strong winds followed, except along the northern New England coast. At 11 a. m. of the 13th, with the storm center over western Ontario, and with rapidly rising pressure to the westward, the SW. warnings were extended southward to Norfolk, Va. Moderately strong NW. winds occurred on the following day. At 10:30 p. m. the warnings from Delaware Breakwater to Newburyport, Mass., were changed to NW., and NW. gales were general on the 14th, New York City reporting a maximum wind velocity of 74 mi. hr. from the NW. The warnings south of Delaware Breakwater were also changed to NW. at 11 a. m. of the 14th, and at 10:30 p. m. they were continued where displayed to the northward. The strong winds continued during the 15th along the northern New Jersey and southern New England coasts.

On the evening of the 16th another disturbance from the NW. was central over northeastern Ohio, with a more moderate secondary center over the Virginia Capes, and at 10 p. m. storm warnings were ordered along the New England coast from Point Judith, R. I., to Eastport, Me., strong NE. winds with snow being forecast for the following day upon the assumption that the secondary disturbance over the Virginia Capes would move rapidly northeastward with rapidly increasing intensity. By the following morning the secondary disturbance was near Nantucket with a barometer reading of 29.30 inches, while the primary disturbance was over northern New York. Snows and gales and rains occurred as forecast, and the westerly winds did not finally subside until the night of the 18th–19th.

On the evening of the 20th a disturbance from Utah and Colorado was over eastern Lake Erie, so at 10:30 p. m. warnings were ordered from Delaware Breakwater to Portland, Me., for strong S. and SW. winds on the following day, to shift to NW. by afternoon. As the disturbance did not develop further during its northeastward progress, nothing more than fresh winds occurred along the coast.

On the morning of the 23d abnormally high pressure, with low temperatures over the northern portion of the country, with a moderate LOW over northeastern Arkansas, indicated the approach of strong NE. winds with snow over the Lake region, so at 10 a. m. advisory warnings to that effect were sent to open ports on Lake Michigan. Subsequent conditions were in accord with the warning.

On the morning of the 24th there was a moderate LOW over southwestern Virginia, with continued abnormally high pressure to the northward, and therefore at 11 a. m. NE. storm warnings were ordered along the New England coast from Point Judith, R. I., to Newburyport, Mass., and strong NE. winds and snow occurred as forecast. On the following morning there was a still more moderate LOW over the eastern portion of the Gulf of Mexico, with persistent high pressure to the northward and northeastward, and at 10:30 a. m. NE. storm warnings were ordered along the Atlantic coast from Fort Monroe, Va., to Jacksonville, Fla. This warning was also generally verified.

On the morning of the 26th there was a well-defined LOW over northwestern Minnesota, with a rapid eastward movement, and with high pressure on either side, so advisory warnings were sent to open ports on Lake Michigan for fresh S. and SW. winds, shifting to strong NW. with snow. Subsequent conditions were in accord with the forecast.

During the 29th and 30th there was a great and very rapid rise in pressure over the Northwest, following a moderate LOW that had moved fast across Canada, and at 10 p. m. of the 30th NW. storm warnings were ordered along the Atlantic coast from Provincetown, Mass., to Sandy Hook, N. J. At 10 a. m. of the 31st, with a great high area over Canada, NE. warnings were ordered south of Sandy Hook as far as Morehead City, N. C. These warnings were verified.

COLD-WAVE AND FROST WARNINGS.

On the morning of the 1st, cold-wave warnings were ordered for portions of New England, the Middle and South Atlantic States, east Tennessee and the Upper

Ohio Valley, and warnings of frost as far south as northwestern Florida. These warnings were fully verified on the following morning, freezing temperatures having been reported to the Gulf coast.

On the morning of the 2d, with high pressure and low temperatures continuing to the westward, warnings of frost, or freezing temperature, were repeated to the Southern States as far south as central Florida. These warnings were also fully verified. Some additional warnings were issued on the morning of the 3d, the limit of prospective frost being extended to southern Florida, and on the following morning frost occurred as far south as Miami, Fla. Another morning of frost was then forecast, and more frosts were reported on the morning of the 5th. Interior frosts on the morning of the 6th as far south as the 25th parallel of latitude were then forecast with success.

Special 1 p. m. observations on the 8th indicated the further development and movement of a disturbance then over Mississippi, with rapidly rising pressure to the northwestward; so at 3 p. m. cold-wave warnings were issued for temperatures near or below the freezing point for central and southern Mississippi, and at 10 p. m. for Alabama, extreme northwest Florida and central and eastern Tennessee. The warnings were repeated on the morning of the 9th, and extended to the interior of the South Atlantic States, except Florida, to the upper Ohio Valley, southern Virginia and northwestern New England. These warnings were generally verified, although the cold wave was somewhat delayed, and in some localities the required minimum temperatures were not reached.

On the morning of the 10th general frost, or freezing temperature, warnings were sent throughout the east Gulf States and the South Atlantic States as far south as northern Florida, and they were verified on the following morning, conditions occurring as forecast, except over northern Florida, where some cloudiness prevailed.

No warnings were issued for the moderate cold wave over the Lake region on the morning of the 14th, although colder weather had been forecast.

On the morning of the 17th cold weather with high pressure covered the Northwest, following the marked disturbance over the northeast, and local cold-wave warnings were ordered for the latter section, and frosts forecast for northern and central Florida, as the low pressure extended southward along the entire Atlantic coast. The cold-wave warnings were only partially justified, and there were no frosts on the following morning. Freezing temperature forecasts for the morning of the 19th over the Southeast also failed of verification owing to the rapid eastward movement of another disturbance from the west.

On the evening of the 20th a cold high area was closely following a disturbance over western New York, and warnings of a cold wave in about 48 hours were ordered at 10 p. m. for southern Ohio, West Virginia, and southwestern Pennsylvania. This warning also failed technically, although there was a marked fall in temperature.

On the morning of the 21st cold-wave warnings were ordered for northwestern New England, the interior of eastern New York, northeastern Pennsylvania, central and eastern Tennessee, southeastern Kentucky, northwestern Alabama, and northeastern Mississippi. The cold waves occurred as forecast in the northeast but failed in the South on account of the persistence of a trough of moderately low pressure over that section, a decided fall in temperature not occurring until the 24th.

Local cold waves that occurred on the morning of the 24th over northern New England, the central and southwestern portions of eastern New York, and over northeastern Pennsylvania were forecast, as was also the decided fall in temperature in the South, but the local cold waves in Michigan were not forecast beyond a prediction of colder weather.

Cold-wave warnings issued on the morning of the 25th for the South were not verified, low pressure persisting over the eastern portion of the Gulf of Mexico.

On the morning of the 26th cold waves were forecast by the night of the 27th for Upper Michigan, and temperatures below zero from 4° to 16° F. were reported on the morning of the 28th. The local cold waves on the morning of the 28th over Lower Michigan, and those of the 28th–29th over interior New York and northern New England were forecast, the cold wave extending by the morning of the 29th over southern New England which had not been covered by the warnings beyond a forecast of colder weather.

Cold-wave warnings issued on the night of the 29th–30th for Michigan, and on the morning of the 30th for northern New York and northern New England, were followed by a severe cold wave on the 31st, but the warnings were far from being sufficient, as the cold wave extended throughout the Middle Atlantic States and New England.

ICE-STORM WARNINGS.

On the morning of Thursday, January 22, pressure distribution was highly favorable for the occurrence of sleet, or ice storms, over the Ohio Valley and Tennessee. A narrow trough of relatively low pressure extended from Louisiana to east Tennessee, with marked cold and high pressure to the northward, and somewhat less marked high pressure to the southeastward, with abnormally high temperatures. The morning forecasts for the 22d stated that rain or ice storms were probable Thursday night or Friday in the Ohio Valley and Tennessee, and they occurred as forecast, the limits of ice formation extending eastward in less pronounced form into central Pennsylvania and the mountain districts of the Virginias and the Carolinas.

From press comments received it appears that this forecast was of enormous value to the transportation, telegraph, telephone, and lighting companies.

The conditions essential to the occurrence of sleet or ice storms and heavy snowstorms are nearly identical, except as to the temperature distribution over the southern regions covered by the high pressure. If the temperatures in this section are abnormally high there will be (1) an overrunning of a mass of abnormally warm air from the southern high pressure high area, with its large moisture content; (2) the precipitation of this moisture in the form of rain when it reaches and rises over the cold counter current on the north side; and (3) the freezing of this rain before or when it reaches the surface. If the temperatures in the southern high area are low, or even normal, the precipitation to the northward will usually be in the form of heavy snow.

HEAVY-SNOW WARNINGS.

Warnings of heavy snow issued on the 23d for southern Lower Michigan, the extreme northern portions of Indiana, Ohio, and western Pennsylvania, and for western New York, were generally verified, as were those of the 24th for New England.

Chicago Forecast District.—No warnings were issued during the first half of January, except that advices of much colder weather with snow and fresh northerly winds were sent to the stock interests of Kansas, Nebraska, and Wyoming on the 6th. Cold waves without warnings occurred in northern Wyoming and at Billings, Mont., on the 7th, and at one or two stations in northern Minnesota or northern Wisconsin on the 8th, 9th, 13th, and 14th.

On the 16th cold-wave warnings were issued for eastern Montana, northeastern Wyoming, and the extreme western portions of the Dakotas, and cattle warnings for South Dakota, Wyoming, and western Nebraska. These warnings were not verified, except in northeastern Montana and extreme western North Dakota. A cold wave without warning occurred at Duluth, Minn., on the 17th. Cold-wave warnings were issued for portions of Montana, Wyoming, and the Dakotas on the 18th and 19th. On the 20th the warnings were extended to cover Kansas, Missouri, extreme eastern Nebraska, and portions of Iowa, Minnesota, and Wisconsin. The warnings of the 18th and 19th were partially verified, and those of the 20th were fully verified except in southern Missouri.

The next warnings were issued on the morning of the 23d for western and central Iowa, the eastern portions of Nebraska and Kansas, and limited areas in Minnesota, Missouri and Wyoming, and they failed of verification, although the sea-level pressure had increased to 31 inches over the northeastern slope of the Rockies. On the 24th cold-wave warnings were issued for extreme eastern Minnesota and central Iowa and were verified in the latter section only.

During the 25–26th a disturbance of considerable energy moved rapidly eastward over the northern tier of States and was followed by a decided increase in pressure and a cold wave as far east as Wisconsin and north-central Iowa. Warnings were issued for the entire area affected.—*Chas. L. Mitchell.*

Denver Forecast District.—The month opened with a continuation of the high-pressure conditions in the Plateau region and on the western slope that prevailed in December. A southwestern disturbance overspread the district, however, early in the first decade. It was attended by remarkably heavy rains in parts of Arizona. At Yuma the rainfall for the 36 hours, ending 8 p. m. January 4th was 1.26 inches, or about three times the monthly normal. On the morning of the 7th the center of the disturbance was in southwest Colorado, while abnormally high pressure had overspread the middle and north Pacific States and the eastern slope. A warning of a moderate cold wave was issued for parts of Utah, Colorado, and New Mexico. The 24-hour fall in temperature was not sufficient to verify the warnings, but much lower temperatures followed within 48 hours. The following low readings were reported: Modena, 8° below zero (F.); Durango, 8° below (F.); Grand Junction, 12° below (F.); and Gallup, 2° below (F.). High pressure become reestablished west of the mountains by the 9th and this condition continued until the 20th. A southwestern LOW formed on that date and dominated the weather in the greater part of the district until the 24th, when the barometric pressure again built up on the western slope and continued during the remainder of the month. No warnings were issued after the 7th, except for parts of eastern Colorado. A moderate cold-wave warning was issued for the extreme northeast portion of northeast Colorado on the morning of the 17th and again on the evening of the 19th. The warning of the 17th failed of verification, owing to the rapid eastward movement of the HIGH. The warning of the 19th was fully verified. A moderate cold-wave warning was issued for eastern Colorado on the morning of the 20th, as high barometric conditions had overspread the northeastern slope. The warning was followed by a sharp fall in temperature in eastern Colorado, with verifying temperatures except near the foothills.—*Frederick W. Brist.*

New Orleans Forecast District.—Cold-wave warnings were issued at 3:30 p. m. January 7, for Arkansas and the northern portion of east Texas, and extended at 10 p. m. to the southwestern portion of east Texas, and on the 8th at 10 a. m. for Port Arthur, Tex., and on the 9th at 10 a. m. for southern Louisiana. The temperatures recorded and the fall in temperature justified the warnings except at a few stations.

Cold-wave warnings were issued January 20 at 10 a. m. for Oklahoma and the extreme northwestern portion of Arkansas; they were extended at 10:25 p. m. over the remainder of Arkansas, northwestern Louisiana, and the northern portion of east Texas except the extreme west portion, and on the morning of the 21st were extended over southern Texas and continued over northwestern Louisiana. There was a decided fall in temperature which justified the warnings.

Cold-wave warnings were issued January 23, 10:30 p. m., for Arkansas, Louisiana, and the southern portion of east Texas, and were repeated on the 24th at 10 a. m. for Louisiana and Port Arthur and Galveston. The warnings were justified over only a portion of the area. No cold wave occurred without warning.

Storm warnings were ordered displayed on the Texas and Louisiana coasts on January 5 and 6, and on the Texas coast on the 7th. Verifying winds occurred at a few stations during the displays. No general storm occurred without warning.

Low-temperature warnings were issued for live stock and other interests on January 20, 21, 23, and 24, for considerable portions of the district.

Fire-weather warnings were issued January 5, 7, and 8, —*I. M. Cline.*

San Francisco Forecast District.—Quite cold weather prevailed during the latter part of the first and early part of the second decades. Frequent heavy to killing frosts occurred in California during this period and frost warnings were issued daily. During this cold spell some citrus fruit was injured in the upper San Joaquin Valley.

Small-craft warnings were ordered at the Strait of Fuca on the 2d and 3d, and at the mouth of the Columbia River and at Washington stations on the 29th. NW. storm warnings were ordered from Port Harford to San Diego on the 3d; NE. storm warnings from Eureka to San Francisco on the 7th; SW. storm warnings at the mouth of the Columbia River and Washington stations on the 17th, 18th, and 24th; and SE. storm warnings at the same stations on the 27th.—*G. H. Willson.*

RIVERS AND FLOODS, JANUARY, 1920.

A. J. HENRY, Meteorologist in Charge.

In general the floods of the month were neither severe nor long continued. The rivers of Texas, the Cumberland of Tennessee, the rivers of Kentucky, and the lower Ohio were in flood for several days and the Mississippi below Cairo carried more water than is usual for a midwinter month. The rivers of Alabama and southeastern Mississippi were again in flood, although the floods were much less severe than in the previous month. The estimated loss due to floods appears in the table below.

Estimated flood loss, January, 1920.

Rivers of—	Tangible property, bridges, etc.	Crops. Matured.	Crops. Prospective.	Live stock.	Suspension of business.	Value of warnings.
Mississippi (SE.)	$2,100	$2,000	....	$5,270	$8,000	$20,000
Alabama	2,300	13,500	$50,400	18,500	5,000	100,500
				16,700	1,900	168,500
Tennessee	1,000	12,700	6,300	....	23,150	12,100
South Carolina	....	....	....	400	425	16,000
Arkansas	....	2,700	....	500	....	....
Texas	50,000	....	20,000	13,000	20,000	60,000
Total	55,400	30,900	76,700	54,370	58,475	376,600

TABLE I.—*Flood stages during month of January, 1920.*

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
ATLANTIC DRAINAGE.					
Santee:	Feet.			Feet.	
Rimini, S. C.	12	28	(*)	15.6	31
Ferguson, S. C.	12	30	(*)	13.2	31
Saluda:					
Chappells, S. C.	14	27	29	15.4	28
Broad:					
Carlton, Ga.	11	27	27	11.0	27
EAST GULF.					
Alabama:					
Montgomery, Ala.	35	27	(*)	42.4	29
Selma, Ala.	35	27	(*)	45.1	30
Coosa:					
Lock No. 4, Lincoln, Ala.	17	28	(*)	17.2	28–30
Tombigbee:					
Demopolis, Ala.	39	25	(*)	46.6	31
Pearl:					
Jackson, Miss.	20	24	(*)	27.6	29
Columbia, Miss.	18	27	31	18.7	29
Pearl River, La.	13	29	(*)	14.6	31
MISSISSIPPI.					
Ohio:					
Cloverport, Ky.	40	28	(*)	42.6	29
Evansville, Ind.	35	14	15	35.8	15
Do.	35	27	(*)	40.3	30–31
Henderson, Ky.	33	15	15	33.0	15
Do.	33	28	(*)	38.3	31
Mount Vernon, Ind.	35	29	(*)	38.6	31
Shawneetown, Ill.	35	29	(*)	37.5	31
Kiskiminetas:					
Saltsburg, Pa.	8	10	13	12.0	10
Mononghela:					
Greensboro, Pa.	20	24	24	22.0	24
Lock No. 4, Pa.	31	24	24	31.3	24
Little Kanawha:					
Glenville, W. Va.	22	23	23	22.3	23
Licking:					
Farmers, Ky.	25	9	10	26.0	10
Falmouth, Ky.	28	9	9	28.1	9
Kentucky:					
Frankfort, Ky.	31	10	11	34.3	10
Do.	31	25	27	33.3	26

* Continued into February.

TABLE I.—*Flood stages during month of January, 1920*—Continued.

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
MISSISSIPPI—continued.					
Kentucky—Continued.	Feet.			Feet.	
Jackson, Ky.	24	22	24	30.0	24
Beattyville, Ky.	30	23	24	35.0	24
High Bridge, Ky.	30	9	10	33.8	10
Do.	30	24	26	31.7	25–26
Green:					
Lock No. 6, Brownsville, Ky.	30	9	14	40.8	11
Do.	30	23	27	39.1	25
Lock No. 4, Woodbury, Ky.	33	9	17	47.4	12
Do.	33	23	30	45.6	26
Lock No. 2, Rumsey, Ky.	34	10	(*)	41.7	17
Cumberland:					
Burnside, Ky.	50	24	24	50.6	24
Celina, Tenn.	45	25	28	48.3	26
Carthage, Tenn.	40	25	30	44.5	27
Nashville, Tenn.	40	25	(*)	44.1	30
Clarksville, Tenn.	46	25	(*)	47.9	31
Lock D, Dover, Tenn.	49	26	(*)	50.7	31
Holston, North Fork:					
Mendota, Va.	8	23	23	9.0	23
Clinch:					
Clinton, Tenn.	25	25	25	29.0	25
Arkansas City, Ark.	42	(†)	1	44.3	‡28
St. Francis:					
Marked Tree, Ark.	17	22	(*)	17.2	23–27
Yazoo:					
Yazoo City, Miss.	25	(†)	(*)	27.8	2–4
Tallahatchie:					
Swan Lake, Miss.	25	(†)	6	28.6	‡15–16
Do.	25	24	(*)	28.1	31
Ouachita:					
Arkadelphia, Ark.	18	9	9	19.0	9
Camden, Ark.	30	11	18	36.6	13–14
Do.	30	25	(*)	35.5	27
Atchafalaya: §					
Melville, La.	37	(†)	4	37.1	‡30–2
Petit Jean:					
Danville, Ark.	20	9	13	22.6	10
Do.	20	24	28	24.7	28
White:					
Batesville, Ark.	23	24	25	24.3	25
Georgetown, Ark.	22	27	(*)	22.8	31
Black:					
Black Rock, Ark.	14	24	(*)	20.2	25
Cache:					
Patterson, Ark.	9	9	13	9.7	10–11
Do.	9	21	(*)	10.3	25
Sulphur:					
Finley, Tex.	24	12	17	25.6	13
Do.	24	26	(*)	26.0	28–29
Ringo Crossing, Tex.	20	9	15	23.2	10–11
Do.	20	24	28	24.7	25
Cypress:					
Jefferson, Tex.	18	13	16	19.0	14
Do.	18	27	30	21.1	27
WEST GULF.					
Trinity:					
Dallas, Tex.	25	7	10	30.4	9
Do.	25	13	14	29.8	13
Do.	25	23	27	33.2	25
Trinidad, Tex.	28	10	(*)	35.3	31
Long Lake, Tex.	40	16	20	40.7	18
Liberty, Tex.	25	17	(*)	28.4	31
Sabine:					
Logansport, La.	25	24	(*)	33.3	27
Bon Weir, Tex.	20	26	(*)	22.0	28
Neches:					
Rockland, Tex.	20	25	(*)	27.2	27
Colorado:					
Columbus, Tex.	28	24	25	31.8	25
Guadalupe:					
Victoria, Tex.	16	14	18	22.1	17
Do.	16	25	29	22.8	27
PACIFIC.					
Willamette:					
Eugene, Oreg.	10	27	27	11.0	27
Oregon City, Oreg.	10	27	30	11.5	28
Santiam:					
Jefferson, Oreg.	10	26	27	12.5	26

*Continued into February.
†Continued from December.
§ Gulf drainage.

DAILY PRECIPITATION WHICH CAUSED THE DESTRUCTIVE FLOODS IN EAST GULF STATES IN DECEMBER, 1919.

The daily precipitation at rainfall stations in the watersheds of the rivers in severe flood in the east Gulf States, in December, 1919 (see this REVIEW 47:894), has been adjusted to a 24-hour basis ending at 8 a. m., seventy-fifth meridian time, and is given in the small table below for the four days ending December 10, 1919.

Average daily precipitation in east Gulf States Dec. 7–10, 1919.

Watershed.	Number of stations.	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Total.	Drainage area.
							M.²
Pearl River, Miss	13	0.80	2.32	2.65	0.29	6.06	8,024
Pascagoula River, Miss	7	0.02	2.25	4.60	0.88	7.56	7,694
Coosa and tributaries, Ala	15	0.70	2.01	2.54	1.26	6.51	....
Coosa, Ga	4	0.68	1.11	2.86	1.00	5.65	....
Tallapoosa, Ala	7	0.24	1.64	2.98	3.47	8.33	....
Cahaba, Ala	5	1.31	2.25	4.16	0.67	8.39	....
Alabama and tributaries, Ala	32	0.59	2.00	3.00	1.90	7.49	23,820
Chattahoochee, Ga	14	0.58	1.30	2.03	2.50	6.41	9,131
Flint, Ga	9	0.21	1.19	1.20	0.99	3.59	8,131
Oconee, Ga	6	0.34	0.99	1.22	1.58	4.13	5,346
Ocmulgee, Ga	8	0.17	1.40	0.81	1.14	2.52	6,148
Savannah, Ga	10	0.35	1.35	1.69	1.63	5.02	11,402

MEAN LAKE LEVELS DURING JANUARY, 1920.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Feb. 4, 1920.]

The following data are reported in the Notice to Mariners of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during January, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.06	580.06	571.38	245.31
Above or below—				
Mean stage of December, 1919	−0.25	−0.10	−0.43	−0.43
Mean stage of January, 1919	−0.18	−0.72	−0.80	−0.78
Average stage for January, last 10 years	+0.03	+0.14	−0.25	−0.07
Highest recorded January stage	−0.70	−2.59	−2.17	−2.29
Lowest recorded January stage	+1.20	+1.00	−0.42	+1.51
Average relation of the January level to—				
December level		−0.2	−0.1	0.0
February level		0.0	0.0	−0.1

* Lake St. Clair's level: In January -573.10 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JANUARY, 1920.

By J. WARREN SMITH, Meteorologist in Charge.

The month on the whole was rather favorable for agricultural interests in most sections of the country. Much mild and pleasant weather for the season was experienced from the Great Plains westward and also in the South, which permitted of considerable outdoor work. It was mostly cold and disagreeable, however, from the Ohio Valley and Lake region eastward and northeastward, and winter farm activities were at a standstill in these districts during most of the month. Frequent rains and wet soil hindered field work in the lower Mississippi Valley States, and drought retarded the growth of vegetation in the south Atlantic and lower Pacific coast districts, but otherwise moisture conditions were not, as a rule, unfavorable.

The weather was mostly favorable for winter grains, except for the frequency of alternate freezing and thawing conditions in portions of the Ohio Valley and some lack of moisture in the west-central Great Plains. Winter oats and other grain crops made satisfactory progress in the southern States, and cereals were well protected by snow cover from the Lake region eastward. There was some damage to tender truck in the South by frost, but on the whole hardy winter truck did well.

The generally mild weather and absence of storms were favorable for stock in the West and Northwest and considerable grazing areas became available by reason of snow melting. In the far Northwest stock recuperated considerably from the effects of the severe weather of the preceding month, but ranges continued poor in California as a result of the continued drought.

The weather, in general, was not unfavorable for orchards, although considerable damage was done from the Ohio Valley eastward by the severe ice storm the latter part of the month. It was mostly favorable for citrus fruit in California and Florida, and no widespread frost damage was experienced.

CLIMATOLOGICAL TABLES.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 174 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th Meridian time, and for about 37 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)...........	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches).......	3.00	1.80	1.40	1.20	1.06	1.00	0.94	0.90	0.87	0.84	0.80

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends. In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given; also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 35 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, pages 13–16.

Chart I.—*Hydrographs* for several of the principal rivers of the United States.

Chart II.—*Tracks of centers* of HIGH areas; and

Chart III.—*Tracks of centers* of LOW areas. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th Meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sea-level and standard gravity.

Chart IV.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin R, Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated, or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—*Isobars and isotherms at sea-level, and prevailing wind directions.* The pressures have been reduced to sea-level and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sea-level plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction t_o–t, or temperature on the sea-level plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sea-level temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Charts IX, X, etc.—*North Atlantic weather maps of particular days.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1920.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	47.0	+ 2.0	Wetumpka	81	23	Oneonta	10	5	6.80	+ 2.20	Mobile	11.70	Tuskegee	3.27
Arizona	44.3	+ 1.2	Gila Bend	82	29	Chin Lee	−13	10	2.02	+ 0.58	Sunflower Ranger Station.	4.90	Tuba City	0.30
Arkansas	39.6	− 1.7	Dardanelle	82	20	Bergman	11	4†	6.49	+ 2.09	Booneville	12.83	Bentonville	2.27
California	48.5	+ 2.7	Tustin (near)	95	17	Portola	− 3	7	0.85	− 4.56	Crescent City	4.18	4 stations	0.00
Colorado	26.9	+ 2.8	Trinidad	76	18	Hermit	−37	9	0.67	− 0.36	Durango	2.86	4 stations	0.00
Florida	61.1	+ 2.2	4 stations	87	17†	2 stations	21	5	2.61	− 0.28	De Funiak Springs	7.65	Key West	0.07
Georgia	48.6	+ 2.2	Bainbridge	84	24	Ramhurst	4	5	4.90	+ 0.89	Newnan	8.09	Brunswick	1.43
Hawaii (December)	70.6	+ 0.8	Waianae	91	30	Glenwood	48	17	5.64	− 2.77	Awini	15.93	Pearl Harbor Naval Station.	0.04
Idaho	24.7	+ 0.9	Murphy	63	26	Stanley	−31	7	1.17	− 1.05	Avery	5.75	3 stations	0.00
Illinois	22.1	− 4.8	Carbondale	69	20	Rockford	−18	24	1.54	− 1.03	Shawneetown	4.55	3 stations	0.45
Indiana	23.0	− 5.9	Rome	66	20	Howe	−19	25	2.22	− 0.89	Princeton	5.60	Greencastle	0.66
Iowa	16.7	− 1.2	Thurman	58	29	Elkader	−26	4	0.42	− 0.63	Northwood	1.05	Denison	T.
Kansas	31.6	+ 1.5	Lakin	78	18	Centralia	− 4	25	0.28	− 0.45	Sedan	1.65	10 stations	T.
Kentucky	33.4	− 1.8	Harlan	72	20	Beattyville	− 6	5	6.72	+ 2.33	Russellville	11.43	Williamstown	3.01
Louisiana	52.8	+ 1.6	Houma	88	22	Calhoun	20	2	6.73	+ 2.29	Kelly	11.26	Grand Coteau	4.02
Maryland-Delaware	27.8	− 5.0	3 stations	64	9	Oakland, Md	−10	6	2.47	− 0.73	Crisfield, Md	3.93	Western Port, Md	1.20
Michigan	11.5	− 8.9	Houghton Lake (near).	45	11	Sidnaw	−43	25	1.39	− 0.70	Grand Marais	3.55	Bloomingdale	0.27
Minnesota	4.3	− 3.6	Lynd	54	29	Roseau	−43	23	1.00	+ 0.24	Red Lake Falls	2.28	Artichoke Lake	0.11
Mississippi	47.3	+ 0.4	Shubuta	84	23	6 stations	15	4†	6.70	+ 1.75	Anguilla	11.17	Columbus	3.68
Missouri	28.6	− 1.4	Caruthersville	72	19	3 stations	− 5	10†	1.57	− 0.65	Caruthersville	7.46	Edgerton	0.10
Montana	22.1	+ 3.0	Three Forks	64	14†	Malta	−43	24	0.99	− 0.07	Haugan	4.07	Renova	0.03
Nebraska	27.1	+ 5.4	2 stations	75	29†	Gordon	−21	24	0.17	− 0.39	2 stations	0.55	4 stations	0.00
Nevada	34.2	+ 4.1	Beatty	84	29	San Jacinto	−19	8	0.30	− 0.90	Owyhee	1.52	Thorne	0.00
New England	13.6	− 7.0	Waterbury, Conn	62	27	Van Buren, Me	−42	20†	2.30	− 1.09	Plymouth, Mass	3.95	Winslow, Me	0.79
New Jersey														
New Mexico	35.8	+ 1.6	Deming	82	19†	2 stations	−22	10	0.86	− 0.11	Mogollon Ranger Station.	3.66	Maxwel, near	0.00
New York	13.9	− 9.2	Scarsdale	52	27	Wanakena	−39	31	2.25	− 0.62	Palermo	4.22	Appleton	1.03
North Carolina	40.1	− 0.9	3 stations	80	24	Banners Elk	−10	5	3.17	− 0.69	Highlands	9.79	Hatteras	0.53
North Dakota	2.8	− 2.1	Hettinger	49	30†	Berthold Agency	−44	24	0.95	+ 0.41	Westhope	2.97	Hettinger	0.00
Ohio	22.1	− 6.7	2 stations	65	20	Paulding	−11	25	2.61	− 0.67	Green	5.60	Wauseon	0.70
Oklahoma	36.5	− 2.4	Kenton	78	18	Hooker	− 6	9	1.87	+ 0.42	Hugo	6.20	Kenton	0.35
Oregon	35.2	+ 1.2	Brookings	71	9†	Blitzen	−28	8	2.22	− 2.73	Cascade Locks	10.41	Reservoir No. 3	0.09
Pennsylvania	20.9	− 7.1	Punxsutawney	59	12	Saegerstown	−23	15	2.47	− 0.85	George School	5.35	New Castle	1.00
Porto Rico														
South Carolina	46.2	+ 0.7	Georgetown	85	9	Walhalla	6	5	3.66	+ 0.22	Winthrop College	8.00	Oaks	1.00
South Dakota	18.5	+ 2.1	2 stations	65	25†	Pollock	−34	24	0.34	− 0.22	2 stations	1.30	2 stations	0.00
Tennessee	38.9	0.0	Newport	76	21	Mountain City	− 6	5	6.36	+ 1.89	Springville	12.03	Knoxville	2.94
Texas	45.6	− 2.8	Brownsville	90	21	Lieb	− 1	9	4.01	+ 2.26	Conroe	9.84	Claude	0.25
Utah	26.5	+ 1.0	Springdale	71	28†	East Portal	−26	11	0.78	− 0.76	Hurricane	2.20	3 stations	0.00
Virginia	33.6	− 2.7	2 stations	75	21	Burkes Garden	− 9	3	2.46	− 0.84	Elk Knob	5.73	Woodstock	0.83
Washington														
West Virginia	28.7	− 4.0	Charleston	77	20	Pickens	−11	3	4.12	+ 0.23	Logan	7.26	Harpers Ferry	0.40
Wisconsin	7.4	− 6.6	2 stations	42	27†	Winter	−40	18	1.36	+ 0.21	Mondovi	2.50	Prairie du Chien	0.48
Wyoming	23.8	+ 4.6	Pine Bluff	68	29	Moran	−33	8	0.53	− 0.41	Moran	2.87	2 stations	0.01

†Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, January, 1920.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England.							**16.8**	**− 7.5**										**73**	**2.51**	**− 1.0**										**6.2**		
Eastport	76	67	85	29.99	30.08	+ .08	11.5	− 8.6	39	1	20	−19	31	3	35	11	6	72	2.07	− 1.8	14	10,046	nw.	61	e.	17	9	10	12	5.9	20.2	13.3
Greenville, Me.	1,070	6		28.86	30.10		4.6		34	8	14	−29	31	−5	35				2.84		11						12	6	13		28.3	28.5
Portland, Me.	103	82	117	30.01	30.14	+ .09	14.6	− 7.4	41	8	23	−14	31	6	31	12	5	70	3.49	− 0.3	11	6,628	nw.	31	w.	18	11	8	12	5.3	24.2	19.4
Concord	288	70	79	29.80	30.13	+ .08	13.8	− 7.4	44	27	24	−18	26	4	35				1.46	− 1.9	10	3,617	nw.	18	nw.	21	12	9	10	5.3	18.3	10.9
Burlington	404	11	48	29.69	30.18	+ .13	6.4	− 9.9	36	8	16	−27	31	−4	41				1.29	− 0.5	12	6,986	s.	62	s.	26	7	7	17	6.2	21.2	16.0
Northfield	876	12	60	29.16	30.18	+ .13	4.8	−10.3	41	27	18	−32	31	−8	46	3	1	87	1.24	− 1.2	18	4,996	n.	26	sw.	17	6	11	14	6.8	26.2	11.0
Boston	125	115	188	29.99	30.13	+ .05	21.0	− 8.0	48	27	30	− 8	31	12	30	18	11	66	2.72	− 1.1	12	8,328	w.	45	w.	18	7	10	14	6.6	24.8	10.4
Nantucket	12	14	90	30.09	30.10	+ .06	26.4	− 5.7	50	27	32	5	16	20	22	24	21	81	3.84	+ 0.4	16	13,604	nw.	48	sw.	18	4	6	21	7.5	12.5	T.
Block Island	26	11	46	30.10	30.12	+ .05	25.0	− 6.4	45	1	32	0	31	19	28	23	20	80	2.75	− 1.1	16	17,153	w.	60	w.	18	9	4	18	6.8	4.6	0.5
Providence	160	215	251	29.95	30.14	+ .08	20.8	− 6.4	48	27	28	− 6	31	13	31	18	13	74	2.60	− 1.8	16	9,917	nw.	58	nw.	14	8	8	15	6.1	17.2	7.3
Hartford	159	122	140	29.98	30.17	+ .10	19.3	− 6.2	44	27	27	− 8	31	11	29	17	11	73	3.39	− 0.4	15	5,650	n.	31	nw.	14	8	8	15	6.3	15.8	7.9
New Haven	106	74	153	30.05	30.18	+ .10	21.4	− 5.9	48	27	29	− 4	31	14	31	18	14	74	2.80	− 1.1	16	7,914	n.	32	w.	18	10	9	12	5.8	8.7	3.2
Middle Atlantic States.							**26.8**	**− 4.6**										**71**	**2.30**	**− 0.9**										**6.4**		
Albany	97	102	115	30.00	30.21	+ .14	14.1	− 8.4	42	27	23	−17	31	5	38	12	8	70	1.73	− 0.9	11	5,921	nw.	30	s.	21	12	8	11	5.6	18.4	9.0
Binghamton	871	10	84	29.19	30.17	+ .09	15.2	− 7.9	43	27	25	−13	26	6	41				1.77	− 0.2	10	4,532	nw.	30	w.	13	4	7	20	7.5	16.5	8.0
New York	314	414	454	29.82	30.18	+ .08	24.1	− 6.1	49	27	32	− 3	31	17	29	20	12	63	2.23	− 1.6	14	14,926	nw.	74	nw.	14	4	12	15	7.0	7.8	1.6
Harrisburg	374	94	104	29.81	30.23	+ .13	23.1	− 5.6	50	30	29	5	19	17	31	20	14	67	2.10	− 0.7	10	5,717	nw.	34	w.	14	5	10	16	6.8	7.3	T.
Philadelphia	117	123	190	30.08	30.22	+ .11	26.8	− 3.0	49	30	34	5	31	20	28	23	17	68	2.71	− 0.7	12	9,116	nw.	37	n.	31	8	7	16	6.6	5.9	0.4
Reading	325	81	98	29.85	30.23		23.0		45	30	29	3	31	17	26	20	15	72	2.74	− 0.8	11	6,219	nw.	31	nw.	14	7	8	16	6.8	6.0	1.6
Scranton	805	111	119	29.30	30.21	+ .12	18.7	− 6.8	39	1	26	− 6	31	11	24	17	13	77	2.79	0.0	13	6,305	sw.	36	sw.	13	2	11	18	7.3	18.2	2.2
Atlantic City	52	37	48	30.13	30.19	+ .08	28.3	− 4.2	53	30	35	7	31	21	29	25	20	75	2.87	− 0.5	15	6,367	nw.	29	nw.	14	11	4	16	5.9	2.6	0.0
Cape May	18	13	49	30.20	30.22	+ .10	29.0	− 5.1	49	30	36	7	31	22	29	26	21	75	3.38	0.0	10	7,775	nw.	34	nw.	14	11	5	15	5.7	1.7	0.0
Sandy Hook	22	10	57	30.16	30.19		24.6		42	1	31	4	31	19	26	22	17	75	2.19		12	13,752	nw.	56	nw.	14	7	11	13	6.4	6.1	1.0
Trenton	190	159	183																													
Baltimore	123	100	113	30.09	30.23	+ .11	28.6	− 4.8	58	30	35	9	3	22	33	25	18	66	1.87	− 1.4	9	5,430	n.	24	n.	31	12	3	16	6.1	2.0	0.0
Washington	112	62	85	30.09	30.22	+ .09	28.7	− 4.2	59	30	36	9	3	22	32	24	17	66	2.30	− 1.1	9	6,079	nw.	42	nw.	14	9	6	16	6.3	2.7	0.0
Lynchburg	681	153	188	29.44	30.21	+ .08	34.4	− 1.4	67	9	44	9	3	25	37	30	23	68	1.64	− 2.1	10	6,419	w.	36	n.	2	11	4	16	6.1	1.0	0.0
Norfolk	91	170	205	30.12	30.22	+ .09	37.4	− 3.0	72	21	46	14	5	29	38	33	27	70	2.14	− 1.2	9	11,071	n.	45	sw.	9	10	5	16	6.2	1.5	T.
Richmond	144	11	52	30.06	30.23	+ .10	34.2	− 3.8	68	9	43	10	3	26	38	29	23	68	2.02	− 0.1	9	6,553	ne.	21	sw.	9	11	4	16	6.2	T.	0.0
Wytheville	2,304	49	55	27.73	30.20	+ .06	32.2	− 0.8	62	9	41	3	3	23	32	29	24	75	2.29	− 2.0	9	5,974	w.	42	sw.	9	7	7	17	6.5	T.	0.0
South Atlantic States.							**46.3**	**+ 1.2**										**75**	**2.30**	**− 1.5**										**5.9**		
Asheville	2,255	70	84	27.79	30.23	+ .08	38.4	+ 3.0	67	9	48	4	5	29	40	34	30	75	1.90	− 2.8	13	6,876	nw.	33	n.	13	9	7	15	6.0	4.6	0.0
Charlotte	779	55	62	29.35	30.21	+ .06	39.8	− 0.6	68	21	49	10	5	30	32	35	30	71	3.81	− 0.5	10	4,789	ne.	32	nw.	17	7	8	16	6.5	2.2	0.0
Hatteras	11	12	50	30.18	30.19	+ .05	43.8	− 2.0	68	21	51	22	5	37	29	40	38	83	0.53	− 4.4	8	12,670	n.	52	n.	4	5	10	16	6.7	T.	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.80	30.22	+ .09	39.0	− 1.4	69	24	49	10	5	29	36	35	30	76	3.28	− 0.3	12	6,729	ne.	32	sw.	21	9	6	16	6.5	1.3	0.0
Wilmington	78	81	91	30.13	30.22	+ .08	46.7	+ 1.1	73	21	56	13	5	38	33	41	36	72	1.10	− 2.4	10	5,929	sw.	29	n.	31	7	12	12	6.3	T.	0.0
Charleston	48	11	92	30.15	30.20	+ .05	51.0	+ 2.0	76	22	59	18	5	43	24	45	40	77	1.60	− 1.8	8	8,700	sw.	36	w.	17	10	7	14	5.8	0.0	0.0
Columbia, S. C.	351	41	57	29.85	30.25	+ .10	45.8	+ 0.7	75	24	55	13	5	37	29	40	35	72	3.18	− 0.1	9	6,030	n.	34	sw.	9	8	12	11	5.7	0.0	0.0
Greenville, S. C.	1,039	113	122	29.07	30.19		41.4		64	9	50	12	5	32	31	37	32	74	5.83		12	6,917	ne.	43	w.	17	12	4	15	5.8	0.5	0.0
Augusta	180	62	77	30.01	30.21	+ .05	48.3	+ 2.4	78	24	58	15	5	30	32	43	39	76	4.30	+ 0.2	8	5,106	nw.	30	nw.	17	9	3	19	6.7	0.0	0.0
Savannah	65	150	194	30.14	30.21	+ .06	53.0	+ 3.1	77	24	62	17	5	44	25	46	42	75	2.14	− 1.0	8	10,085	ne.	44	w.	17	13	4	14	5.2	0.0	0.0
Jacksonville	43	209	245	30.15	30.20	+ .05	57.3	+ 3.4	79	22	65	25	5	50	28	51	47	79	1.21	− 1.9	9	10,833	ne.	46	ne.	31	17	8	6	4.0	0.0	0.0
Florida Peninsula.							**67.8**	**+ 3.3**										**78**	**1.06**	**− 1.7**										**3.6**		
Key West	22	10	64	30.11	30.13	+ .03	71.0	+ 2.2	82	25	76	52	5	66	13	65	63	81	0.07	− 1.9	2	7,591	e.	24	e.	20	23	6	2	2.6	0.0	0.0
Miami	25	71	79	30.13	30.16		68.6	+ 1.3	81	17	75	35	4	63	27	63	59	76	0.41	− 3.0	4	6,666	e.	24	se.	30	11	12	8	4.8	0.0	0.0
Sand Key	23	39	72	30.08	30.11	+ .01	70.7		81	25	73	53	5	68	13	66	63	78				11,200	e.				20	9	2	2.6	0.0	0.0
Tampa	35	79	92	30.14	30.18	+ .06	63.7	+ 6.3	82	22	73	35	5	55	29	57	53	77	2.70	− 0.1	8	4,831	ne.	23	ne.	29	14	10	7	4.4	0.0	0.0
East Gulf States.							**49.8**	**+ 2.4**										**79**	**6.85**	**+ 1.8**										**6.8**		
Atlanta	1,174	190	216	28.95	30.22	+ .07	42.7	+ 0.5	70	22	51	13	5	34	27	40	37	81	7.69	+ 2.4	14	9,689	nw.	40	nw.	4	8	1	22	7.1	T.	0.0
Macon	370	78	87	29.81	30.22	+ .06	48.2	+ 2.6	77	23	58	17	5	39	32	43	37	72	4.40	− 0.8	10	5,650	ne.	28	ne.	25	8	6	17	6.6	0.0	0.0
Thomasville	273	49	58	29.90	30.20	+ .04	53.9	+ 2.9	77	22	63	23	5	45	28	48	43	75	3.24	− 0.9	9	4,174	ne.	19	ne.	25	11	6	14	5.8	0.0	0.0
Pensacola	56	149	185	30.12	30.18	+ .04	55.0	+ 2.7	71	16	62	26	5	48	28	51	48	80	5.51	+ 1.5	13	11,567	ne.	46	w.	16	6	9	16	6.8	0.0	0.0
Anniston	741	9	57	29.41	30.22	+ .06	45.1	+ 2.9	73	22	54	11	5	36	35				7.99	+ 2.7	15	5,159	nw.	25	sw.	1	6	9	16	6.8	0.7	0.0
Birmingham	700	11	48	29.45	30.24	+ .08	46.2	+ 0.9	74	22	54	15	5	38	34	41	37	77	5.37	0.0	16	6,132	n.	29	se.	8	7	8	16	6.8	T.	0.0
Mobile	57	125	161	30.12	30.18	+ .03	53.6	+ 3.8	75	21	61	26	5	46	32	50	47	83	11.70	+ 6.8	18	8,920	n.	38	se.	6	6	8	17	6.8	0.0	0.0
Montgomery	223	100	112	29.97	30.22	+ .06	50.3	+ 2.6	80	23	58	20	5	42	28	45	41	75	8.66	+ 3.6	16	6,022	n.	26	nw.	16	9	4	18	6.6	0.0	0.0
Corinth	469	6					41.0		71	20	50	16	5	32	32				6.47		11		n.				6	15	10			
Jackson	304	5					48.6		70	21	56	23	5	42	34				6.98		14		ne.				9	7	15			
Meridian	375	85	93	29.80	30.21	+ .05	48.7	+ 3.7	77	21	56	20	5	41	31	45	41	79	6.50	+ 1.0	12	5,120	ne.	21	w.	9	7	6	18	6.9	0.0	0.0
Vicksburg	247	65	74	29.92	30.21	+ .06	48.1	+ 1.1	77	21	56	25	5	40	32	44	41	82	8.65	+ 3.0	11	5,358	n.	27	s.	8	6	4	21	7.5	0.0	0.0
New Orleans	53	76	84	30.12	30.18	+ .05	56.0	+ 3.0	81	21	63	29	5	49	25	52	49	83	5.66	+ 1.0	13	5,501	ne.	24	e.	5	9	6	16	6.7	0.0	0.0
West Gulf States.							**45.8**	**− 0.4**										**81**	**5.17**	**+ 2.2**										**6.7**		
Shreveport	249	77	93	29.95	30.23	+ .09	46.2	0.0	77	20	53	28	9	39	29	42	38	78	7.06	+ 2.6	14	5,205	n.	26	s.	20	9	5	17	6.7	T.	0.0
Bentonville	1,303	11	44	28.81	30.22	+ .08	34.8	+ 0.7	66	19	44	14	1	25	37				2.27	− 0.4	6	4,153	n.	20	s.	20	15	3	13	5.4	8.7	0.0
Fort Smith	457	79	94	29.73	30.22	+ .08	38.8	+ 0.5	72	20	47	22	1	31	33	35	31	77	3.89	+ 1.4	10	4,750	e.	24	e.	5	14	17	0	5.9	1.6	0.0
Little Rock	357	139	147	29.84	30.23	+ .08	40.8	+ 0.2	73	20	48	22	5	33	38	37	33	80	9.19	+ 4.4	10	6,286	n.	32	s.	16	9	5	17	6.4	0.4	0.0
Brownsville	57	4	26				58.4		90	21	68	35	5	48	36				1.13		7		n.									
Corpus Christi	20	69	77	30.16	30.18	+ .08	52.6	− 0.9	74	7	60	33	26	45	27	49	46	85	2.74	+ 0.5	10	7,741	n.	37	se.	7	6	2	23	7.4	0.0	0.0
Dallas	512	109	117	29.67	30.23		42.8		76	20	51	24	2	35	32				4.93		10	5,095	nw.	31	s.	20	8	6	17	6.7	0.4	0.0
Fort Worth	670	106	114	29.47	30.20	+ .08	43.0	− 1.3	77	20	52	23	2	34	36	40	36	80	3.48	+ 2.6	8	6,305	nw.	28	nw.	24	9	5	17	6.5	T.	0.0
Galveston	54	106	114	30.12	30.18	+ .05	54.0	+ 1.3	73	21	60	35	9	48	30	51	48	85	7.09	+ 3.5	13	8,923	n.	42	n.	24	5	10	16	6.8	0.0	0.0
Houston	138	111	121	30.02	30.18		52.1	− 0.8	78	21	60	33	9	44	31				6.44		12	6,025	n.	25	ne.	24	8	6	17	6.7	0.0	0.0
Palestine	510	64	72	29.67	30.22	+ .10	46.0	− 0.5	77	20	53	29	9	39	35	41	38	81	7.10	+ 3.2	11	5,536	n.	29	s.	20	6	7	18	7.2	0.0	0.0
Port Arthur	34	58	66	30.12	30.16		52.6		75	21	59	32	2	46	30	49	47	85	6.96		11	7,248	ne.	42	ne.	23	7	3	21	7.4	0.0	0.0
San Antonio	701	119	132	29.45	30.20	+ .10	49.4	− 1.7	79	20	58	30	26	41	33	44	39	75	3.36	+ 1.7	12	6,010	ne.	31	nw.	24	7	5	19	6.9	T.	0.0
Taylor	582	55	63	29.60	30.23	+ .12	45.8	− 1.7	77	20	54	27	26	38	34				5.52	+ 2.7	12	6,324	n.	30	n.	24	8	4	19	6.9	T.	0.0

TABLE I.—*Climatological data for Weather Bureau stations, January, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F		°F	°F	°F	°F	%	In	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee.							30.5	− 2.4										78	3.99	+ 1.5										6.8		
Chattanooga	762	189	213	29.41	30.24	+ .08	42.5	+ 1.9	68	20	50	13	5	34	38	38	33	71	4.37	− 1.2	14	6,871	sw.	38	nw.	4	7	6	18	6.7	T.	0.0
Knoxville	996	102	111	29.13	30.21	+ .06	41.1	+ 3.6	68	23	50	10	5	32	40	37	32	73	2.94	− 2.0	11	5,710	sw.	30	w.	1	6	9	16	7.1	0.1	0.0
Memphis	399	76	97	29.82	30.27	+ .11	39.3	− 1.0	70	20	46	19	5	33	40	36	32	79	6.01	+ 0.8	10	6,162	n.	27	nw.	23	10	6	15	6.4	T.	0.0
Nashville	546	168	191	29.66	30.26	+ .10	38.6	+ 0.6	69	20	47	13	3	30	40	34	30	76	7.35	+ 2.5	9	6,864	nw.	34	w.	9	8	7	16	6.7	T.	0.0
Lexington	989	193	230	29.12	30.24	+ .11	30.1	+ 0.1	61	20	38	2	3	23	32	.....	.....	.....	5.26	+ 1.4	15	10,335	sw.	54	se.	8	6	8	17	6.9	1.4	0.0
Louisville	525	219	255	29.67	30.28	+ .14	30.5	− 3.7	64	20	37	5	3	24	33	27	23	76	4.77	+ 0.9	11	9,166	w.	39	sw.	9	10	6	15	5.8	2.1	0.0
Evansville	431	139	175	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Indianapolis	822	194	230	29.33	30.26	+ .14	22.2	− 6.0	46	30	30	1	3	15	29	20	17	80	2.01	− 0.8	10	9,776	ne.	34	nw.	1	10	5	16	6.2	9.7	0.3
Terre Haute	575	96	129	29.61	30.26	.....	23.5	.....	48	30	31	− 6	4	16	26	21	17	77	1.64	.....	8	7,765	nw.	27	nw.	20	11	6	14	6.0	8.5	0.0
Cincinnati	628	11	51	29.55	30.26	+ .14	25.4	− 4.9	59	20	33	− 1	3	18	30	23	21	84	3.48	+ 0.1	12	6,602	ne.	29	nw.	2	6	7	18	6.8	1.1	0.0
Columbus	824	179	222	29.33	30.25	+ .14	22.2	− 6.4	49	20	30	− 1	3	15	37	20	17	81	2.64	− 0.3	14	9,503	w.	42	nw.	2	5	11	15	6.8	12.5	1.6
Dayton	899	181	216	29.22	30.22	.....	23.4	− 5.5	48	20	31	− 1	3	16	33	21	18	81	1.80	− 1.2	14	8,613	ne.	36	nw.	2	7	8	16	6.5	7.3	0.1
Pittsburgh	842	353	410	29.29	30.23	+ .12	24.4	− 6.3	52	20	32	1	3	16	38	21	16	75	2.80	− 0.1	14	9,731	sw.	46	sw.	9	4	8	19	7.6	11.1	T.
Elkins	1,947	59	67	28.07	30.23	+ .13	28.2	− 0.8	64	23	38	− 3	3	18	37	25	22	83	4.66	+ 1.3	20	4,765	w.	30	w.	13	4	5	22	7.9	5.8	0.0
Parkersburg	638	77	82	29.57	30.26	+ .14	28.4	− 2.9	62	20	36	1	5	20	40	25	21	78	3.83	+ 0.6	12	5,194	nw.	34	w.	2	6	4	21	7.5	3.1	0.0
Lower Lake Region.							15.7	− 8.8										79	2.19	− 0.5										7.0		
Buffalo	767	247	280	29.33	30.20	+0.13	15.6	− 9.1	37	27	23	−11	31	8	36	14	11	83	2.58	− 0.7	20	15,921	w.	60	w.	3	1	6	24	8.7	23.8	21.0
Canton	448	10	61	29.65	30.17	.....	4.1	−12.2	37	27	15	−36	16	−7	57	.....	.....	.....	1.69	− 1.5	18	8,794	w.	43	sw.	27	11	6	14	5.8	18.0	17.3
Oswego	335	76	91	.....	30.20	+ .13	14.0	− 9.9	37	1	22	−18	31	6	37	.....	.....	.....	1.84	− 1.3	20	10,865	s.	40	nw.	18	0	2	29	.....	.....	.....
Rochester	523	97	102	29.61	30.21	+ .14	16.1	− 7.9	38	27	24	− 9	31	9	34	14	9	74	3.24	+ 0.1	17	8,630	w.	36	w.	1	2	8	21	8.0	35.4	16.5
Syracuse	597	97	113	29.50	30.19	+ .12	13.9	− 9.1	40	1	22	−19	31	5	38	.....	.....	.....	3.66	+ 1.5	20	9,833	nw.	55	s.	20	5	7	19	7.3	37.1	16.0
Erie	714	130	166	29.40	30.22	+ .14	18.1	− 8.4	41	20	25	− 4	31	11	36	16	13	80	1.73	− 1.3	15	12,079	sw.	60	se.	20	5	7	19	7.2	21.2	7.8
Cleveland	762	190	201	29.38	29.24	+ .15	19.0	− 7.2	43	20	26	0	25	12	34	17	12	75	1.96	− 0.5	16	11,340	ne.	48	nw.	14	5	11	15	6.9	17.1	4.4
Sandusky	629	62	103	29.52	30.23	+ .14	18.9	− 7.4	39	26	25	− 2	25	13	34	.....	.....	.....	1.32	− 0.8	11	10,997	w.	42	ne.	30	7	9	15	6.5	11.5	3.8
Toledo	628	208	243	29.54	30.26	+ .17	17.9	− 7.7	40	7	25	− 4	31	11	34	16	12	76	1.61	− 0.3	9	11,846	sw.	44	w.	13	9	9	13	5.8	13.1	5.2
Fort Wayne	856	113	124	29.29	30.26	.....	18.1	− 8.8	38	26	25	− 3	3	11	37	16	12	76	0.90	.....	12	8,422	w.	32	w.	2	13	4	14	5.8	12.5	3.4
Detroit	730	218	245	29.41	30.25	+ .17	16.8	− 7.5	36	7	23	− 7	31	10	30	15	12	81	1.73	− 0.2	10	10,598	w.	40	w.	13	8	11	12	6.2	18.3	7.0
Upper Lake Region.							11.0	− 7.2										82	1.49	− 0.5										6.5		
Alpena	609	13	92	29.52	30.22	+ .18	10.4	− 8.3	34	26	20	−19	25	1	33	9	6	83	1.53	− 0.7	17	9,667	nw.	38	se.	20	5	11	15	6.8	19.1	15.5
Escanaba	612	54	60	29.55	30.26	+ .21	8.2	− 6.3	32	7	17	−14	18	0	29	7	5	91	1.44	− 0.1	12	7,669	nw.	33	nw.	13	10	14	7	4.9	15.7	13.0
Grand Haven	632	54	89	29.53	30.26	+ .19	15.9	− 8.6	36	12	22	− 5	25	9	31	15	11	80	1.50	− 1.3	16	10,255	e.	48	w.	13	6	8	17	7.2	19.2	9.4
Grand Rapids	707	70	87	29.44	30.26	+ .20	16.0	− 7.8	37	26	22	− 8	25	10	29	14	10	76	1.19	− 1.6	11	5,295	nw.	33	nw.	13	6	10	15	6.4	15.8	8.0
Houghton	684	62	99	29.47	30.24	+ .19	6.2	− 8.3	30	12	14	−26	25	−2	36	.....	.....	.....	3.41	+ 1.4	18	7,605	w.	40	nw.	13	4	5	22	7.8	35.6	28.0
Lansing	878	11	62	29.25	30.24	.....	13.2	− 8.8	34	13	21	−14	25	5	29	12	9	84	1.34	− 0.8	18	5,627	nw.	25	w.	13	6	10	15	6.7	17.9	8.0
Ludington	637	60	66	29.51	30.24	.....	15.4	.....	36	26	22	− 4	31	9	34	15	12	84	1.25	.....	17	9,489	e.	40	sw.	12	2	11	18	7.8	20.2	9.5
Marquette	734	77	111	29.41	30.27	+ .23	9.2	− 6.7	34	29	16	−11	25	2	24	7	4	84	1.84	− 0.2	21	6,895	nw.	41	s.	26	2	10	19	7.7	21.6	23.3
Port Huron	638	70	120	29.50	30.24	+ .18	13.6	− 8.2	35	7	21	−10	31	6	33	12	9	82	1.37	− 0.5	14	9,640	nw.	37	nw.	1	5	16	10	6.0	19.2	12.0
Saginaw	641	69	77	29.51	30.25	.....	12.6	.....	36	26	20	−12	25	5	35	12	10	86	0.74	− 1.5	8	6,864	nw.	30	sw.	12	6	14	11	6.2	11.1	6.0
Sault Sainte Marie	614	11	52	29.49	30.24	+ .21	4.4	− 8.9	31	7	14	−23	25	−5	33	3	− 1	80	1.68	− 0.5	17	5,850	nw.	40	nw.	13	8	11	12	6.0	18.7	21.0
Chicago	823	140	310	29.34	30.28	+ .18	18.8	− 4.9	38	29	25	− 5	2	13	23	18	13	74	1.11	− 0.9	10	10,018	nw.	38	ne.	23	8	9	14	5.9	12.4	1.0
Green Bay	617	109	144	29.55	30.26	+ .20	9.2	− 5.4	35	26	17	−14	2	1	30	8	3	76	0.98	− 0.7	10	9,122	w.	40	ne.	23	7	8	16	6.7	13.6	10.5
Milwaukee	681	125	139	29.48	30.26	+ .18	15.4	− 4.4	37	29	23	−11	2	8	26	14	11	83	1.57	− 0.4	9	9,404	w.	42	se.	16	7	11	13	6.1	22.1	8.6
Duluth	1,133	11	47	28.96	30.27	+ .18	3.0	− 7.4	37	29	11	−25	18	−5	32	2	0	91	1.13	+ 0.2	13	9,848	nw.	50	nw.	12	14	5	12	5.2	11.7	7.4
North Dakota.							3.1	− 1.0										86	0.78	+ 0.2										6.5		
Moorhead	940	8	57	29.23	30.33	+ .19	1.4	− 1.3	34	12	10	−27	21	−8	35	0	− 2	86	0.94	+ 0.2	13	6,906	n.	30	nw.	26	9	7	15	6.3	14.4	14.0
Bismarck	1,674	8	57	28.40	30.31	+ .18	7.4	+ 0.7	39	31	17	−32	21	−2	33	5	3	84	0.52	0.0	7	6,273	nw.	29	nw.	17	6	10	15	6.1	6.9	4.0
Devils Lake	1,482	11	44	28.58	30.28	+ .16	−2.3	− 2.6	32	12	6	−32	24	−11	33	− 3	− 4	90	0.74	+ 0.1	9	7,947	nw.	32	nw.	12	7	8	16	6.5	10.0	9.6
Grand Forks	835	12	89	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Williston	1,878	41	48	28.13	30.24	+ .13	5.8	− 0.7	37	28	15	−37	24	−3	29	5	2	84	0.92	+ 0.3	7	5,699	se.	32	nw.	12	7	7	17	6.5	8.4	7.2
Ellendale	1,457	10	56	28.61	30.27	.....	1.2	.....	38	12	15	−27	24	−3	40	5	3	86	0.65	.....	14	10,658	nw.	55	nw.	20	6	6	19	7.1	8.0	7.0
Upper Mississippi Valley.							18.1	− 3.4										82	1.15	− 0.6										5.9		
Minneapolis	918	102	208	29.22	30.26	.....	7.7	.....	39	12	15	−17	2	0	36	.....	.....	.....	1.84	+ 1.2	12	8,565	nw.	39	se.	31	8	10	13	6.2	18.5	12.6
St. Paul	837	236	261	29.32	30.28	+ .17	7.0	− 3.9	38	12	16	−17	2	−2	35	.....	.....	.....	1.80	+ 0.9	12	8,871	se.	36	nw.	26	7	14	10	5.8	22.1	14.6
La Crosse	714	11	48	29.45	30.28	+ .17	9.4	− 5.8	39	26	18	−16	4	0	34	.....	.....	.....	1.10	0.0	10	3,954	n.	19	s.	26	7	7	17	6.7	14.1	11.0
Madison	974	70	78	29.18	30.30	+ .20	10.0	− 6.5	35	12	18	−14	2	2	28	9	6	84	0.84	− 0.7	10	7,732	nw.	30	ne.	23	7	5	19	7.3	9.6	11.8
Wausau	1,247	4	.....	28.80	30.21	.....	5.4	.....	34	29	15	−21	25	−4	30	.....	.....	.....	.....	.....	13	.....	nw.	.....	.....	.....	5	8	18	6.9	17.0	24.0
Charles City	1,015	10	49	29.15	30.29	+ .15	10.0	− 1.4	38	29	19	−15	25	1	32	9	7	88	0.65	−0.3	8	5,144	nw.	25	sw.	12	8	9	14	6.5	8.4	2.0
Davenport	606	71	79	29.59	30.30	+ .18	17.2	− 3.6	42	12	24	− 6	4	10	29	16	13	85	0.44	−1.1	7	6,318	nw.	27	sw.	12	12	7	12	5.5	5.0	T.
Des Moines	861	84	97	29.32	30.27	+ .13	18.4	− 2.0	45	29	26	− 5	25	11	29	17	14	80	0.44	−0.8	7	5,739	n.	29	sw.	12	9	10	12	6.1	4.7	0.9
Dubuque	698	81	96	29.52	30.32	+ .20	13.4	− 4.9	40	26	21	−13	4	6	34	12	9	83	0.63	−0.9	7	5,264	nw.	25	nw.	20	7	12	12	6.3	11.5	7.0
Keokuk	614	64	78	29.50	30.31	+ .17	22.5	− 1.2	49	29	30	0	25	15	31	20	15	72	0.38	−1.3	3	6,012	n.	32	s.	12	11	8	12	5.0	3.8	T.
Cairo	356	87	93	29.86	30.25	+ .09	33.2	− 1.6	66	20	40	13	4	26	35	30	27	81	3.48	−0.3	9	7,762	n.	39	n.	24	8	6	17	6.5	T.	0.0
Peoria	609	11	45	29.59	30.29	+ .17	18.6	− 4.5	40	29	26	− 9	25	11	34	17	15	88	0.93	−1.3	6	5,940	n.	25	s.	12	15	4	12	5.2	8.5	1.7
Springfield, Ill	644	10	91	29.56	30.27	+ .14	23.0	− 3.3	45	30	30	0	4	16	24	21	18	83	0.79	−1.5	10	7,114	nw.	29	nw.	1	15	4	12	5.0	4.8	T.
Hannibal	534	74	109	29.66	30.27	+ .14	24.2	− 2.5	48	29	32	4	4	16	28	.....	.....	.....	0.96	−1.2	9	6,765	n.	28	sw.	12	13	6	12	5.2	7.6	T.
St. Louis	567	265	303	29.63	30.26	+ .12	28.4	− 2.6	55	30	35	5	4	21	26	25	20	73	1.85	−0.4	11	9,400	nw.	35	sw.	12	15	6	10	4.9	9.3	T.
Missouri Valley.							24.7	+ 3.6										79	0.34	− 0.5										5.5		
Columbia, Mo	781	11	84	29.38	30.25	+ .12	26.9	− 0.3	55	30	35	5	2	18	30	.....	.....	.....	0.71	− 1.5	7	6,211	n.	24	sw.	12	15	5	11	4.5	8.4	0.0
Kansas City	963	161	181	29.18	30.26	+ .11	29.2	+ 3.0	58	29	38	9	28	21	29	26	21	73	0.35	− 0.8	5	9,213	n.	35	n.	20	18	4	9	4.1	0.4	0.0
St. Joseph	967	11	49	29.18	30.26	.....	27.2	.....	60	29	35	6	25	20	33	24	19	74	0.32	.....	5	6,075	n.	30	n.	20	16	8	7	4.1	1.7	T.
Springfield, Mo	1,324	98	104	28.78	30.24	+ .10	31.4	+ 0.1	60	20	39	12	9	24	35	29	26	85	2.36	− 0.3	7	7,781	n.	32	w.	3	19	2	10	4.2	12.8	0.0
Iola	984	11	50	29.15	30.25	+ .11	30.5	+ 2.9	61	30	39	7	9	22	31	.....	.....	.....	0.76	− 0.2	5	5,515	s.	27	n.	20	10	11	10	5.5	7.9	0.0
Topeka	987	92	107	.....	.....	.....	30.0	+ 4.4	62	29	38	9	25	22	37	.....	.....	.....	0.24	− 0.7	3	7,453	n.	36	n.	20	13	9	9	4.7	0.7	0.0
Drexel	1,299	10	53	28.78	30.24	.....	21.6	.....	51	29	30	0	21	14	30	20	18	88	0.14	.....	2	8,127	n.	35	sw.	25	7	9	15	6.5	1.9	T.
Lincoln	1,189	11	84	28.93	30.26	+ .11	25.7	+ 4.5	58	29	33	2	9	18	31	23	20	80	0.22	− 0.4	2	7,251	n.	28	n.	20	7	8	16	6.3	1.8	0.0
Omaha	1,105	115	122	29.03	30.28	+ .13	23.2	+ 2.7	53	29	30	4	21	16	28	21	17	77	0.28	− 0.4	4	6,687	nw.	39	ne.	19	10	9	12	6.1	2.9	0.0
Valentine	2,598	47	54	27.39	30.22	+ .10	25.9	+ 7.7	61	29	38	−14	24	14	44	22	18	80	0.17	− 0.5	4	6,810	nw.	34	nw.	20	6	13	12	5.8	3.2	0.0
Sioux City	1,135	94	164	28.99	30.28	+ .13	19.1	+ 3.5	51	29	27	− 3	9	11	33	17	14	81	0.33	− 0.2	8	8,824	nw.	56	nw.	20	3	14	14	6.5	3.2	0.2
Huron	1,306	59	74	28.81	30.29	+ .13	14.8	+ 5.3	51	29	25	−18	24	5	48	13	9	77	0.30	− 0.2	9	8,427	nw.	36	n.	20	8	11	12	5.7	3.0	T.
Pierre	1,572	70	75	28.50	30.26	+ .13	19.0	+ 5.1	52	14	28	−15	24	10	33	16	12	77	0.16	− 0.3	4	5,690	nw.	37	nw.	20	12	4	15	5.7	2.4	0.0
Yankton	1,233	49	57	28.88	30.28	+ .12	20.3	+ 4.9	55	29	30	− 6	24	11	43	.....	.....	.....	0.25	− 0.3	3	6,369	nw.	31	nw.	20	3	10	18	7.4	2.8	T.

TABLE I.—*Climatological data for Weather Bureau stations, January, 1920*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Departure from normal.	Days with 0.01 inch or more.	Wind: Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F		° F	° F	° F	° F	%	In	In.		Miles								0-10	In.	In.
Northern Slope.							23.3	+ 4.3										72	6.60	− 0.2										5.7		
Billings	3,140	5	.....	.....	.....	.....	21.6	.....	57	19	32	−25	24	11	49	.....	.....	.....	.....	.....	8	.....	sw.	.....	.....	.....	15	10	6	.....	14.0	T.
Havre	2,505	11	44	27.45	30.23	+ .13	13.0	− 0.5	50	14	22	−31	24	3	46	12	10	84	1.14	+ 0.4	10	6,421	sw.	36	sw.	11	7	6	18	7.1	11.4	1.5
Helena	4,110	87	112	25.87	30.22	+ .07	24.7	+ 5.0	54	18	34	− 6	22	16	48	20	14	66	0.66	− 0.3	6	5,223	sw.	54	sw.	18	6	9	16	6.4	8.0	1.8
Kalispell	2,973	48	56	.....	.....	.....	24.2	+ 4.6	48	18	31	2	17	18	28	.....	.....	.....	0.85	− 0.7	8	3,487	nw.	28	sw.	18	6	7	18	.....	.....	.....
Miles City	2,371	26	48	27.59	30.28	+ .16	16.3	+ 1.8	46	18	26	−31	24	6	38	13	11	84	1.42	+ 0.8	11	3,793	s.	30	s.	15	10	11	10	5.5	12.4	5.6
Rapid City	3,259	50	58	26.67	30.24	+ .14	26.2	+ 4.7	62	18	38	−16	24	14	54	21	14	65	0.23	− 0.2	5	5,782	n.	36	n.	26	6	12	13	6.2	2.6	0.0
Cheyenne	6,088	84	101	24.01	30.13	+ .08	33.5	+ 7.9	63	29	44	0	8	23	36	25	17	57	0.20	− 0.2	4	11,495	w.	70	w.	19	15	8	8	4.5	2.0	0.0
Lander	5,372	60	68	24.70	30.29	+ .17	20.2	+ 2.8	57	26	32	−18	8	8	44	15	8	63	1.08	+ 0.6	4	2,587	sw.	40	w.	19	10	18	3	4.9	10.8	T.
Sheridan	3,790	10	47	26.15	30.22	.....	22.8	.....	60	18	36	−19	24	9	55	18	14	77	0.81	.....	5	3,214	nw.	38	nw.	19	8	9	14	5.9	13.6	0.8
Yellowstone Park	6,200	11	48	23.92	30.27	+ .13	22.7	+ 5.1	45	31	31	−11	8	14	27	20	15	73	0.28	− 2.0	10	6,880	s.	35	nw.	19	11	8	12	5.9	2.9	8.6
North Platte	2,821	11	51	27.20	30.25	+ .13	28.9	+ 7.5	67	29	40	0	24	18	45	21	20	76	0.07	− 0.4	1	4,959	w.	32	n.	20	14	6	11	5.3	0.6	0.0
Middle Slope.							33.5	+ 4.4										75	0.60	0.0										5.4		
Denver	5,292	106	113	24.77	30.16	+ .11	36.0	+ 6.9	68	19	47	4	8	25	42	28	20	62	0.64	+ 0.2	3	5,129	s.	29	ne.	20	13	7	11	5.3	7.3	0.0
Pueblo	4,685	80	86	25.35	30.16	+ .11	35.0	+ 5.9	71	18	48	0	9	22	47	28	20	64	0.29	− 0.1	3	4,488	nw.	37	nw.	26	11	7	13	5.6	1.0	0.0
Concordia	1,392	50	58	28.72	30.26	+ .12	30.2	+ 5.8	66	29	38	8	25	22	39	26	24	82	0.12	− 0.6	4	5,884	n.	32	ne.	20	10	8	13	6.0	0.4	0.0
Dodge City	2,509	11	51	27.55	30.26	+ .15	32.8	+ 5.5	68	18	45	7	9	21	41	26	22	76	0.07	− 0.4	2	7,150	n.	39	ne.	20	15	6	10	4.5	0.7	0.0
Wichita	1,358	139	158	28.76	30.25	+ .12	31.7	+ 2.0	60	30	40	12	21	24	27	28	25	82	0.41	− 0.4	3	9,002	s.	40	ne.	20	13	8	10	4.9	2.4	0.0
Altus	1,410	5	.....	.....	.....	.....	.....	.....	71	19	48	8	9	27	40	.....	.....	.....	1.78	.....	8	.....	ne.	.....	.....	.....	12	6	13	.....	7.5	0.0
Muskogee	652	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oklahoma	1,214	10	47	28.92	30.25	+ .14	35.2	+ 0.5	70	19	44	9	9	27	33	31	29	83	2.09	+ 0.8	9	9,487	n.	39	n.	7	8	8	15	6.3	10.4	0.0
Southern Slope.							40.5	− 1.0										74	1.76	+ 1.0										5.8		
Abilene	1,738	10	52	28.36	30.22	+ .13	41.4	+ 1.2	74	18	52	18	9	31	37	35	31	75	3.02	+ 2.1	8	5,760	s.	27	n.	20	7	5	19	7.0	0.4	0.0
Amarillo	3,676	10	49	26.37	30.21	+ .15	35.2	+ 1.3	73	19	47	5	9	24	41	29	25	76	1.11	+ 0.5	5	7,417	sw.	29	n.	8	12	8	11	4.9	11.1	0.0
Del Rio	944	64	71	29.17	30.18	+ .12	48.0	− 2.2	73	18	56	27	26	39	34	.....	.....	.....	1.53	+ 0.7	11	5,771	nw.	37	nw.	8	8	5	18	6.5	T.	0.0
Roswell	3,566	75	85	26.47	30.18	+ .14	37.3	− 1.9	73	20	50	− 1	9	25	41	32	27	72	1.38	+ 0.8	7	4,019	s.	28	ne.	7	10	12	9	5.0	13.0	0.0
Southern Plateau.							43.8	+ 3.0										60	0.85	+ 0.1										4.1		
El Paso	3,762	110	133	26.28	30.11	+ .10	44.5	+ 0.4	68	20	54	20	8	34	32	38	31	64	1.06	+ 0.6	8	8,328	nw.	38	e.	14	13	6	12	4.7	3.0	0.0
Santa Fe	7,013	57	66	23.27	30.15	+ .11	33.9	+ 5.4	57	28	44	3	9	24	29	27	20	64	0.31	− 0.3	6	4,726	ne.	30	n.	15	14	6	11	4.9	4.4	0.0
Flagstaff	6,908	8	57	23.37	30.09	+ .04	30.4	+ 3.7	58	19	42	0	7	19	41	26	.....	.....	2.30	.....	9	.....	e.	34	ne.	10	15	7	9	.....	12.5	T.
Phoenix	1,108	76	81	28.88	30.05	+ .02	53.3	+ 3.3	79	30	65	29	9	42	36	46	40	68	1.42	+ 0.2	5	3,359	e.	20	e.	13	17	9	5	3.8	0.0	0.0
Yuma	141	9	54	29.91	30.06	+ .01	55.7	+ 1.0	78	28	66	36	7	45	33	48	40	62	1.47	+ 1.0	6	3,780	n.	25	s.	4	20	6	5	3.1	0.0	0.0
Independence	3,957	9	41	26.08	30.17	+ .10	44.7	+ 4.2	71	16	57	24	9	32	31	34	20	41	0.00	− 0.9	0	5,663	nw.	34	nw.	11	12	15	4	4.0	0.0	0.0
Needles	488	4	.....	29.56	30.07	.....	50.6	.....	70	17	61	30	14	40	34	.....	.....	.....	1.41	.....	4	.....	.....	.....	.....	.....	11	4	16	.....	.....	.....
Middle Plateau.							29.2	+ 0.8										70	0.47	− 0.6										4.3		
Reno	4,532	74	81	25.60	30.24	+ .11	36.9	+ 4.4	64	16	50	10	8	23	38	31	24	64	0.04	− 1.9	2	2,692	w.	26	w.	5	20	7	4	3.1	0.1	0.0
Tonopah	6,090	12	20	24.15	30.18	.....	37.4	.....	65	18	45	8	8	29	22	29	18	49	0.04	− 0.7	1	6,254	se.	48	nw.	5	13	17	1	3.9	T.	0.0
Winnemucca	4,344	18	56	25.77	30.29	+ .13	31.5	+ 2.7	58	26	44	− 4	9	19	37	27	22	72	0.39	− 0.6	3	4,350	ne.	25	n.	6	17	6	8	3.8	3.5	0.0
Modena	5,479	10	43	24.70	30.21	+ .11	28.7	+ 1.2	57	29	40	− 8	9	17	37	24	20	73	0.44	− 0.3	5	4,792	w.	29	ne.	7	17	4	10	4.1	4.9	0.0
Salt Lake City	4,360	163	203	25.76	30.26	+ .11	30.8	+ 2.0	54	19	38	8	11	24	25	27	23	74	1.24	− 0.1	4	3,287	nw.	33	se.	7	14	5	12	4.7	8.7	0.0
Grand Junction	4,602	60	68	25.56	30.31	+ .25	18.2	− 6.5	43	24	28	−14	9	8	36	17	15	90	0.66	+ 0.2	6	2,074	nw.	15	e.	5	11	5	15	6.0	8.1	1.0
Northern Plateau.							29.6	+ 0.7										77	1.15	− 0.7										7.0		
Baker	3,471	48	53	26.60	30.31	+ .15	28.0	+ 4.1	55	16	37	2	8	20	29	25	22	79	1.34	− 1.2	3	4,525	se.	24	sw.	26	10	6	15	5.8	0.8	0.0
Boise	2,739	78	86	27.38	30.34	+ .15	30.1	+ 0.9	56	27	38	8	8	22	26	28	24	70	0.66	− 1.2	6	2,697	nw.	24	w.	6	13	5	13	5.2	2.4	0.0
Lewiston	757	40	48	29.44	30.28	+ .12	32.2	− 2.3	58	19	38	12	7	26	25	.....	.....	.....	2.27	+ 0.7	6	1,820	e.	29	sw.	19	4	4	23	8.2	1.9	0.0
Pocatello	4,477	60	68	25.61	30.30	+ .10	27.0	+ 1.9	55	19	36	− 3	11	18	32	24	20	77	0.14	− 0.5	5	5,091	w.	44	sw.	17	8	10	13	6.0	1.5	0.0
Spokane	1,929	101	110	28.14	30.27	+ .15	28.7	+ 1.0	50	17	34	6	23	23	19	27	24	80	0.96	− 1.3	7	3,906	sw.	35	sw.	17	4	6	21	7.8	6.5	1.1
Walla Walla	991	57	65	29.18	30.30	+ .15	31.6	− 1.6	58	14	36	12	6	27	26	29	26	82	1.55	− 0.5	5	2,914	s.	24	s.	17	3	1	27	8.8	2.7	0.0
North Pacific Coast Region.							40.7	+ 0.6										87	5.80	− 1.1										7.4		
North Head	211	11	56	29.98	30.21	+ .16	42.2	+ 0.4	59	28	46	27	22	38	14	40	38	85	5.34	− 1.3	16	10,471	se.	74	s.	24	9	2	20	7.0	T.	0.0
North Yakima	1,071	4	.....	.....	.....	.....	28.4	.....	60	16	36	10	6	21	27	.....	.....	.....	0.94	.....	3	.....	.....	.....	.....	.....	8	6	17	.....	7.5	.....
Port Angeles	29	8	53	30.19	30.22	.....	38.7	.....	53	17	43	23	22	35	16	.....	.....	.....	3.48	− 2.0	15	3,754	s.	37	w.	19	2	1	28	9.1	0.1	0.0
Seattle	125	215	250	30.10	30.24	+ .19	40.2	+ 0.9	63	28	45	24	23	36	19	39	36	87	3.92	− 0.6	13	6,515	se.	48	s.	16	3	4	24	8.5	T.	0.0
Tacoma	213	113	120	30.00	30.23	+ .19	39.5	+ 1.4	63	28	44	20	23	34	21	39	38	91	6.10	+ 0.3	14	4,134	sw.	30	sw.	19	4	3	24	8.3	1.1	0.0
Tatoosh Island	86	7	57	30.07	30.17	+ .19	41.6	+ 0.4	55	28	44	32	21	39	13	40	38	88	13.07	+ 0.9	17	13,497	e.	55	e.	27	7	2	22	7.5	0.7	0.0
Medford	1,425	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Oreg.	153	68	106	30.09	30.25	+ .17	39.4	+ 0.3	57	28	45	23	13	34	24	38	35	83	4.84	− 1.7	11	4,003	nw.	32	sw.	16	8	9	14	5.9	0.0	0.0
Roseburg	510	9	57	29.70	30.26	+ .16	41.2	+ 0.4	67	27	47	26	13	36	21	40	38	89	1.51	− 4.2	8	1,564	nw.	14	s.	24	2	14	15	7.1	0.0	0.0
Middle Pacific Coast Region.							49.5	+ 2.4										71	0.58	− 4.2										4.3		
Eureka	62	73	89	30.13	30.20	+ .10	47.9	+ 1.0	66	13	54	32	7	42	30	46	44	88	1.87	− 5.8	7	3,487	se.	37	nw.	5	13	7	11	5.2	0.0	0.0
Mount Tamalpais	2,375	11	18	27.63	30.13	+ .02	48.5	+ 2.6	71	18	54	29	1	43	23	41	31	58	0.38	− 5.6	4	15,555	ne.	74	n.	7	16	8	7	4.1	0.0	0.0
Point Reyes Light	490	7	18	29.57	30.09	.....	51.3	+ 1.9	78	18	58	37	2	45	25	.....	.....	.....	0.19	.....	5	10,247	se.	67	nw.	5	14	9	8	4.7	0.0	0.0
Red Bluff	332	50	56	29.80	30.16	+ .04	50.4	+ 5.0	78	18	62	30	2	39	41	44	36	63	0.56	− 3.4	5	3,835	nw.	35	nw.	7	19	5	7	3.5	0.0	0.0
Sacramento	69	106	117	30.07	30.14	+ .02	46.8	+ 1.2	67	16	56	29	9	37	30	45	41	78	0.29	− 3.4	3	4,433	se.	33	n.	7	16	4	11	4.4	0.0	0.0
San Francisco	155	208	243	29.96	30.13	+ .02	52.2	+ 2.7	70	18	59	38	14	46	28	46	41	70	0.26	− 4.1	4	5,217	n.	45	ne.	7	15	8	8	4.2	0.0	0.0
San Jose	141	12	110	29.97	30.12	.....	49.4	.....	76	17	61	27	10	38	40	.....	.....	.....	0.10	− 2.8	2	3,681	se.	36	n.	7	15	8	8	3.9	0.0	0.0
South Pacific Coast Region.							53.0	+ 1.9										69	0.61	− 2.2										4.7		
Fresno	327	80	98	29.78	30.15	+ .05	48.2	+ 2.8	72	17	57	26	11	39	31	43	36	67	0.69	− 0.9	1	3,040	nw.	27	nw.	5	15	4	12	4.6	0.0	0.0
Los Angeles	338	159	191	29.72	30.08	.00	56.6	+ 2.3	89	17	65	41	10	48	39	50	45	70	0.50	− 2.3	3	3,967	ne.	28	nw.	5	12	9	10	4.7	0.0	0.0
San Diego	87	62	70	29.97	30.07	.00	54.6	+ 0.6	76	17	62	37	10	48	27	50	45	74	0.43	− 1.6	4	3,776	nw.	34	e.	3	10	6	15	5.7	0.0	0.0
San Luis Obispo	201	32	40	29.90	30.12	+ .03	52.8	+ 1.8	84	17	65	30	10	40	41	45	38	64	0.82	− 3.9	2	2,195	n.	17	ne.	16	15	10	6	3.8	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.97	30.06	.....	74.8	.....	83	4	79	68	25	70	14	.....	.....	.....	6.39	+ 1.8	26	12,370	e.	44		22	7	17	7	5.3	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.73	29.86	.00	80.4	+ 0.3	91	16	89	70	30	72	20	72	70	76	T.	− 1.0	0	7,834	n.	30	n	19	19	12	0	3.5	0.0	0.0
Colon	36	7	97	29.84	29.88	.00	81.6	+ 1.8	87	9	86	73	26	77	12	74	72	76	0.51	− 3.2	9	12,681	n.	32	ne.	10	6	24	1	4.4	0.0	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	22			0.59														0.45			
Albany, N. Y.	16-17			0.54														(*)			
Alpena, Mich.	6-7			0.36														(*)			
Amarillo, Tex.	7-8			0.99														(*)			
Anniston, Ala.	23	2:05 p. m.	5:38 p. m.	1.02	2:24 p. m.	2:55 p. m.	0.01	0.37	0.49	0.57	0.62	0.64	0.74	0.78							
	23-24	6:55 p. m.	7:35 a. m.	1.62	2:23 a. m.	2:50 a. m.	0.36	0.07	0.15	0.23	0.36	0.49	0.54								
Asheville, N. C.	24			0.45														0.16			
Atlanta, Ga.	23	3:15 p. m.	7:35 p. m.	1.03	5:30 p. m.	5:50 p. m.	0.09	0.09	0.29	0.48	0.69										
Atlantic City, N. J.	24			0.81														0.24			
Augusta, Ga.	27-28	9:15 a. m.	D. N. a. m.	1.24	12:02 p. m.	12:29 p. m.	0.12	0.07	0.19	0.24	0.43	0.57	0.64								
Baker, Oreg.	5			0.08														(*)			
Baltimore, Md.	8			0.35														0.15			
Bentonville, Ark.	22			0.83														0.25			
Binghamton, N. Y.	9			0.58														0.08			
Birmingham, Ala.	23	12:25 p. m.	3:04 p. m.	1.22	12:44 p. m.	1:10 p. m.	0.01	0.35	0.65	0.78	0.92	1.00	1.03								
Bismarck, N. Dak.	17			0.20														(*)			
Block Island, R. I.	9			0.89														0.13			
Boise, Idaho.	25-26			0.28														(*)			
Boston, Mass.	24			0.74														0.13			
Buffalo, N. Y.	9			0.65														(*)			
Burlington, Vt.	23-24			0.48														(*)			
Cairo, Ill.	7-8			1.35														(*)			
Canton, N. Y.	23-24			0.38														(*)			
Charles City, Iowa.	5-6			0.37														(*)			
Charleston, S. C.	28			0.69														0.20			
Charlotte, N. C.	16			0.99														0.25			
Chattanooga, Tenn.	23			0.86														0.39			
Cheyenne, Wyo.	6-7			0.13														(*)			
Chicago, Ill.	23-24			0.37														(*)			
Cincinnati, Ohio.	8			1.66														0.26			
Cleveland, Ohio.	8-9			0.85														(*)			
Columbia, Mo.	27			0.72														0.41			
Columbia, S. C.	27			0.72														0.41			
Columbus, Ohio.	7-8			1.47														(*)			
Concord, N. H.	16-17			0.40														(*)			
Concordia, Kans.	6			0.05														(*)			
Corpus Christi, Tex.	23-24			1.12														(*)			
Dallas, Tex.	7			1.20														0.40			
Davenport, Iowa.	23			0.23														(*)			
Dayton, Ohio.	7			0.17														0.13			
Del Rio, Tex.	24			0.15														0.11			
Denver, Colo.	6-7			0.50														(*)			
Des Moines, Iowa.	23			0.28														(*)			
Detroit, Mich.	23			0.46														(*)			
Devils Lake, N. Dak.	15			0.29														(*)			
Dodge City, Kans.	8			0.06														(*)			
Drexel, Nebr.	6			0.11														(*)			
Dubuque, Iowa.	23			0.21														(*)			
Duluth, Minn.	20			0.27														(*)			
Eastport, Me.	17			0.66														(*)			
Elkins, W. Va.	22			1.17														0.20			
Ellendale, N. Dak.	17-18			0.23														(*)			
El Paso, Tex.	23			0.22														0.17			
Erie, Pa.	9			0.53														(*)			
Escanaba, Mich.	5-6			0.47														(*)			
Eureka, Calif.	26			0.39														0.29			
Flagstaff, Ariz.	3-4			0.91														(*)			
Fort Smith, Ark.	22			1.30														0.30			
Fort Wayne, Ind.	8-9			0.27														(*)			
Fort Worth, Tex.	5			1.12														0.24			
Fresno, Calif.	22			0.69														0.32			
Galveston, Tex.	23-24	7:30 p. m.	D. N. a. m.	1.63	9:18 p. m.	9:36 p. m.	0.48	0.22	0.49	0.63	0.72										
Grand Haven, Mich.	6-7			0.30														(*)			
Grand Junction, Colo.	6-7			0.29														(*)			
Grand Rapids, Mich.	6-7			0.33														(*)			
Green Bay, Wis.	15-16			0.33														(*)			
Greenville, S. C.	24			1.00														0.49			
Hannibal, Mo.	22-23			0.39														(*)			
Harrisburg, Pa.	8-9			0.81														(*)			
Hartford, Conn.	8-9			1.00														(*)			
Hatteras, N. C.	26			0.11														0.08			
Havre, Mont.	18-19			0.44														(*)			
Helena, Mont.	25-26			0.29														(*)			
Houghton, Mich.	13			0.72														(*)			
Houston, Tex.	23-24	3:25 p. m.	1:00 p. m.	4.48	5:53 p. m.	6:35 p. m.	0.84	0.10	0.33	0.40	0.43	0.46	0.54	0.62	0.77	0.81					
					1:45 a. m.	2:12 a. m.	2.92	0.09	0.18	0.21	0.32	0.48	0.51								
Huron, S. Dak.	19-20			0.13														(*)			
Independence, Calif.	(‡)			(‡)														(‡)			
Indianapolis, Ind.	8-9			0.83														(*)			
Iola, Kans.	8-9			0.50														(*)			
Jacksonville, Fla.	17			0.63														0.32			
Kalispell, Mont.																					
Kansas City, Mo.	22-23			0.31														(*)			
Keokuk, Iowa.	23			0.28														(*)			
Key West, Fla.	28			0.04														0.03			
Knoxville, Tenn.	23			0.57														0.33			
La Crosse, Wis.	5-6			0.35														(*)			
Lander, Wyo.	6			0.89														(*)			
Lansing, Mich.	23			0.41														(*)			
Lewiston, Idaho.	16			0.61														0.11			
Lexington, Ky.	8			2.08														0.27			
Lincoln, Nebr.	6			0.21														(*)			
Little Rock, Ark.	8			2.85														0.66			
Los Angeles, Calif.	4			0.19														0.07			
Louisville, Ky.	8			2.22														0.41			
Ludington, Mich.	6-7			0.30														(*)			
Lynchburg, Va.	21			0.57														0.12			
Macon, Ga.	25			1.29														0.29			
Madison, Wis.	18-19			0.32														(*)			

* Self-register not in use. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during January, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Marquette, Mich.	6-7			0.30														(*)			
Memphis, Tenn.	21			1.12														0.43			
Meridian, Miss.	8	7:20 p. m.	D. N. p. m.	1.05	8:28 p. m.	9:01 p. m.	0.22	0.15	0.41	0.43	0.49	0.59	0.65	0.69							
Miami, Fla.	29			0.32														0.17			
Milwaukee, Wis.	18-19			0.51														(*)			
Minneapolis, Minn.	5-6			0.61														(*)			
Mobile, Ala.	6-7	9:01 a. m.	D. N. a. m.	3.39	10:23 p. m.	11:14 p. m.	0.34	0.09	0.20	0.38	0.51	0.68	0.85	1.12	1.24	1.31	1.36	1.41			
					12:52 a. m.	1:21 a. m.	2.04	0.06	0.14	0.29	0.47	0.60	0.70								
	22	2:25 p. m.	6:25 p. m.	1.68	5:23 p. m.	5:54 p. m.	1.09	0.00	0.24	0.31	0.41	0.44	0.48	0.57							
Modena, Utah	3-4			0.28														(*)			
Montgomery, Ala.	8-9	D. N. p. m.	D. N. a. m.	1.21	1:27 a. m.	2:11 a. m.	0.11	0.20	0.33	0.53	0.65	0.70	0.71	0.75	0.83	0.91					
Moorhead, Minn.	14-15			0.36														(*)			
Mount Tamalpais, Calif.	4-5			0.16														0.09			
Nantucket, Mass.	9			1.05														0.20			
Nashville, Tenn.	8			2.18														0.64			
New Haven, Conn.	8-9			0.95														(*)			
New Orleans, La.	16			0.89														0.45			
New York, N. Y.	9			0.67														0.12			
Norfolk, Va.	24			0.55														0.19			
Northfield, Vt.	23-24			0.38														(*)			
North Head, Wash.	27			1.04														0.23			
North Platte, Nebr.	10			0.07														(*)			
Oklahoma, Okla.	8			0.73														(*)			
Omaha, Nebr.	6			0.21														(*)			
Oswego, N. Y.	15-16			0.68														(*)			
Palestine, Tex.	22-23	D. N. p. m.	6:10 a. m.	2.16	1:39 a. m.	2:59 a. m.	0.13	0.29	0.47	0.57	0.69	0.75	0.87	1.00	1.08	1.15	1.36	1.50	1.79		
Parkersburg, W. Va.	23			0.93														0.36			
Pensacola, Fla.	30			1.49														0.50			
Peoria, Ill.	23			0.60														(*)			
Philadelphia, Pa.	9			0.59														0.11			
Phoenix, Ariz.	4			0.61														0.25			
Pierre, S. Dak.	22-23			0.13														(*)			
Pittsburgh, Pa.	8			1.21														0.13			
Pocatello, Idaho	22			0.08														(*)			
Point Reyes Light, Calif.	4			0.06														0.05			
Port Angeles, Wash.	17			0.45														0.14			
Port Huron, Mich.	9			0.29														(*)			
Portland, Me.	16-17			1.85														(*)			
Portland, Oreg.	25			3.00														0.31			
Providence, R. I.	9			0.89														(*)			
Pueblo, Colo.	6			0.15														(*)			
Raleigh, N. C.	24			1.01														0.47			
Rapid City, S. Dak.	22			0.13														(*)			
Reading, Pa.	8-9			0.88														(*)			
Red Bluff, Calif.	5			0.21														0.17			
Reno, Nev.	22			0.03														(*)			
Richmond, Va.	24-25			0.88														(*)			
Rochester, N. Y.	23-24			0.73														(*)			
Roseburg, Oreg.	26			0.49														0.11			
Roswell, N. Mex.	7-8			0.61														(*)			
Sacramento, Calif.	5			0.09														0.04			
Saginaw, Mich.	6-7			0.25														(*)			
St. Joseph, Mo.	22-23			0.24														(*)			
St. Louis, Mo.	7-8			0.95														(*)			
St. Paul, Minn.	5-6			0.55														(*)			
Salt Lake City, Utah	5-6			0.64														(*)			
San Antonio, Tex.	5			1.11														0.31			
San Diego, Calif.	4			0.16														0.11			
Sand Key, Fla.	(*)			(*)														(*)			
Sandusky, Ohio	8-9			0.70														(*)			
Sandy Hook, N. J.	9			0.75														0.15			
San Francisco, Calif.	21			0.18														0.03			
San Jose, Calif.	22			0.09														0.03			
San Luis Obispo, Calif.	22			0.80														0.17			
Santa Fe, N. Mex.	3-4			0.21														(*)			
Sault Ste. Marie, Mich.	6-7			0.55														(*)			
Savannah, Ga.	28			0.75														0.59			
Scranton, Pa.	9			0.70														(*)			
Seattle, Wash.	27			0.91														(*)			
Sheridan, Wyo.	19			0.36														(*)			
Shreveport, La.	23			4.00														0.58			
Sioux City, Iowa	6			0.15														(*)			
Spokane, Wash.	24			0.41														(*)			
Springfield, Ill.	22-23			0.34														(*)			
Springfield, Mo.	7-8			1.06														(*)			
Syracuse, N. Y.	23-24			0.77														(*)			
Tacoma, Wash.	16-17			1.16														(*)			
Tampa, Fla.	28			1.49														0.41			
Tatoosh Island, Wash.	14			2.02														0.38			
Taylor, Tex.	23			1.68														0.58			
Terre Haute, Ind.	23			0.61														(*)			
Thomasville, Ga.	1			0.57														0.27			
Toledo, Ohio	9			0.66														(*)			
Tonopah, Nev.	31			0.04														(*)			
Topeka, Kans.	22-23			0.16														(*)			
Trenton, N. J.																					
Valentine, Nebr.	23			0.11														(*)			
Vicksburg, Miss.	23-24	8:05 a. m.	D. N. a. m.	4.90	8:11 a. m.	8:43 a. m.	0.01	0.12	0.28	0.35	0.41	0.47	0.54	0.59							
Walla Walla, Wash.	25-26			1.18														(*)			
Washington, D. C.	21-22			0.62														(*)			
Wausau, Wis.	6			0.27														(*)			
Wichita, Kans.	8			0.17														(*)			
Williston, N. Dak.	17			0.26														(*)			
Wilmington, N. C.	16			0.39														0.12			
Winnemucca, Nev.	21			0.05														0.05			
Wytheville, Va.	21			0.56														0.14			
Yankton, S. Dak.	27			0.21														(*)			
Yellowstone Park, Wyo.	24			0.05														(*)			

* Self-register not in use.

TABLE III.—*Data furnished by the Canadian Meteorological Service, January, 1920.*

Stations.	Altitude above M. S. L. Jan. 1, 1919.	Pressure.			Temperature.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sea-level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	25												
Sydney, C. B. I.	48	29.97	30.02	+0.09	11.9	− 8.6	22.4	1.3	37	−14	1.92	−3.18	18.0
Halifax, N. S.	88	29.92	30.04	+1.07	14.4	− 7.4	24.5	4.3	39	−17	2.90	−2.78	26.9
Yarmouth, N. S.	65	29.96	30.04	+0.04	19.2	− 7.1	27.2	11.3	40	− 4	2.94	−2.46	28.0
Charlottetown, P. E. I.	38	29.98	30.02	+0.06	8.1	− 8.9	16.9	− 0.7	34	−17	1.52	−2.44	15.2
Chatham, N. B.	28	30.03	30.07	+0.10	4.4	− 5.4	16.2	− 7.4	34	−24	1.83	−1.76	18.3
Father Point, Que.	20	30.05	30.08	+0.10	3.7	− 4.3	11.6	− 4.1	30	−24	1.34	−1.51	13.4
Quebec, Que.	296	29.79	30.14	+0.12	2.3	− 6.8	10.8	− 6.2	32	−28	2.62	−1.30	26.2
Montreal, Que.	187	29.95	30.18	+0.14	4.3	− 7.4	11.5	− 2.8	34	−23	2.94	−0.79	29.4
Stonecliffe, Ont.	489	29.56	30.22	+ .20	−2.8	− 9.2	9.4	−14.9	32	−36	1.94	−0.38	19.4
Ottawa, Ont.	236	29.93	30.22	+ .19	2.6	− 7.0	13.1	− 7.9	35	−29	2.90	−0.09	20.0
Kingston, Ont.	285	29.88	30.22	+ .17	9.6	− 7.5	19.3	0.1	36	−22	0.55	−2.90	5.5
Toronto, Ont.	379	29.78	30.22	+ .17	13.0	− 8.4	21.3	4.7	37	−18	2.38	−0.54	23.8
Cochrane, Ont.	930	....	....	....	−7.0	....	2.6	−16.7	29	−39	0.90	....	9.0
White River, Ont.	1,244	29.76	30.18	+ .17	−8.2	− 7.8	6.9	−23.4	28	−48	1.15	−0.54	11.5
Port Stanley, Ont.	592	29.56	30.24	+ .17	13.6	− 9.2	22.4	4.8	55	−14	3.56	+0.57	35.5
Southampton, Ont.	656	29.44	....	....	9.9	−10.5	18.6	1.3	34	−19	3.15	−0.90	31.5
Parry Sound, Ont.	688	29.48	30.24	+ .23	3.3	−10.5	15.1	− 8.4	36	−28	1.19	−2.89	11.9
Port Arthur, Ont.	644	29.49	30.26	+ .19	0.7	− 2.4	11.3	− 9.8	30	−27	0.75	−0.07	7.5
Winnipeg, Man.	760	29.40	30.31	+ .20	−4.0	+ 2.8	3.8	−11.8	27	−37	1.54	+0.66	15.4
Minnedosa, Man.	1,690	28.30	30.26	+ .16	−5.7	+ 1.5	3.5	−14.8	30	−43	0.98	+0.18	9.8
Le Pas, Man.	860	....	....	....	−8.5	....	−0.8	−16.3	28	−40	0.57	....	5.7
Qu'Appelle, Sask.	2,115	27.81	30.23	+ .15	−2.6	− 0.9	6.8	−12.1	34	−41	2.10	+1.60	21.0
Medicine Hat, Alb.	2,144	27.77	30.14	+ .07	9.4	+ 3.9	19.7	− 0.9	46	−40	1.65	+1.08	16.5
Moose Jaw, Sask.	1,759	....	....	....	1.8	....	10.9	− 7.2	36	−38	1.85	....	18.5
Swift Current, Sask.	2,392	27.41	30.19	+ .12	7.9	+ 4.8	17.5	− 1.6	45	−38	0.55	−0.09	5.5
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.36	30.19	+ .19	10.1	− 2.0	20.5	− 0.3	42	−46	3.24	+2.05	31.6
Edmonton, Alb.	2,150	27.76	30.21	+ .18	2.7	+ 0.9	12.7	− 7.3	44	−46	2.02	+1.34	19.9
Prince Albert, Sask.	1,450	28.56	30.27	+ .18	−5.4	+ 3.0	3.6	−14.3	35	−44	1.10	+0.13	11.0
Battleford, Sask.	1,592	28.37	30.24	+ .16	−2.9	+ 3.0	5.2	−11.1	35	−43	1.44	+1.04	14.4
Kamloops, B. C.	1,262	28.96	30.32	+ .36	22.3	− 2.7	28.7	15.8	51	− 9	0.83	+0.01	8.2
Victoria, B. C.	230	29.94	30.20	+ .23	39.2	− 0.7	42.7	35.6	53	−25	5.55	+0.16	0.6
Barkerville, B. C.	4,180	25.63	30.09	+ .20	15.2	− 2.6	21.6	8.7	39	−26	5.72	+3.12	50.8
Triangle Island, B. C.	680	....	....	....	....	....	....	....	....	....	....	....	....
Prince Rupert, B. C.	170	....	....	....	....	....	....	....	....	....	....	....	....
Hamilton, Bermuda.	151	30.04	30.21	+ .08	63.6	+ 2.7	68.3	59.0	74	50	4.04	−0.90	0.0

SEISMOLOGICAL REPORTS.

SEISMOLOGICAL REPORTS FOR JANUARY, 1920.

W. J. HUMPHREYS, Professor in Charge.

Weather Bureau, Washington, D. C., March 3, 1920.

SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

CHARACTER OF THE EARTHQUAKE.

I=noticeable.
II=conspicuous.
III=strong.
d=(terræ motus domesticus)=local earthquake (sensible or felt).
v=(terræ motus vicinus)=near-by earthquake (within 1,000 km.).
r=(terræ motus remotus)=distant earthquake (1,000 to 5,000 km. distant).
u=(terræ motus ultimus)=very distant earthquake (beyond 5,000 km.).
△=distance to epicenter.

PHASES.

P=(undæ primæ)=first preliminary tremors.
PR_n=P waves reflected n times at the earth's surface.
S=(undæ secundæ)=second preliminary tremors.
SR_n=S waves reflected n times at the earth's surface.
PS=transformed waves; longitudinal (P) to transversal (S) or vice versa.
L=(undæ longæ)=long waves in the principal portion.
M=(undæ maximæ)=greatest motion in the principal portion.
C=(coda)=trailers.
O=time at epicenter.
L_{rep1}=Long waves reaching the station from the antiepicenter (40,000 km.$-\triangle$).
L_{rep2}=long waves again reaching the station from the antiepicenter (40,000 km.$+\triangle$).
F=(finis)=end of perceptable trace.

NATURE OF THE MOTION.

i=(impetus)=abrupt beginning.
e=(emersio)=gradual appearance.
T=period=twice time of oscillation.
A=amplitude of earth's movement, reckoned from the zero line.
E, N, or Z attached to a symbol signifies the E-W, the N-S, or the vertical component, respectively, thus:
P_E is the E-W component of P.
P_N is the N-S component of P.
P_Z is the vertical component of P.

$$\mu=\text{micron}, \frac{1}{1,00}\text{ mm.}$$

INSTRUMENTAL CONSTANTS.

T_0=period of instrument.
V=magnification of instrument.
ϵ=damping ratio.

List of instrumental stations from which reports are received.

Location.	Latitude, N.	Longitude, W.	Elevation, meters.	Description of instruments.	Instrumental constants. E-W. V	T_0	ϵ	N-S. V	T_0	ϵ	Institution.	In charge.
	° ′ ″	° ′ ″										
ALABAMA.												
Mobile	30 41 44	88 08 46	60	Wiechert 80-kg., astatic, horizontal pendulum.	......					......	Spring Hill College, seismic observatory.	Cyril Ruhlman, S. J.
ALASKA.												
Sitka	57 03 00	135 30 03	15.2	Two Bosch-Omori 10 and 12 kg.	10	17	......	10	15	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	F. P. Ulrich.
ARIZONA.												
Tucson	32 14 48	110 50 06	769.6	....do	10	17	......	10	18	......	....do	Wm. H. Cullum.
CALIFORNIA.												
Point Loma	32 43 03	117 15 10	91.4	Two-component C. D. West seismoscope.	......					......	Theosophical University	F. J. Dick.
COLORADO.												
Denver	39 40 36	104 56 54	1,655	Wiechert 80-kg., astatic, horizontal pendulum.	......					......	Sacred Heart College, earthquake station.	A. W. Forstall, S. J.
DISTRICT OF COLUMBIA.												
Washington	38 54 25	77 04 24	42.4	Wiechert 200-kg., astatic, horizontal pendulum; *80-kg. vertical.*	165	5.4	0	143	5.2	0	Georgetown University	F. A. Tondorf, S. J.
					VERTICAL: *V, 80; T_0, 3.0; ϵ, 0.*							
Do	38 54 12	77 03 03	21	Marvin, vertical pendulum, undamped, mechanical registration.	110	6.4	......	110	6.4	......	U. S. Weather Bureau	W. J. Humphrey.
HAWAII.												
Honolulu	21 19 12	158 03 48	15.2	Milne seismograph of the Seismol. Comm. Brit. Assoc.	......	18.4	[1]0″.40	......		......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	Frank Neumann.
ILLINOIS.												
Chicago	41 47 00	87 37 00	180.1	Two Milne-Shaw horizontal pendulums, 0.45-kg.	150	12	20:1	150	8	20:1	University of Chicago	H. J. Cox.
KANSAS.												
Lawrence	38 57 30	95 14 58	301.1	Wiechert	177	3.4	4:1	205	3.4	4:1	University of Kansas, department physics and astronomy.	F. E. Kester.
MARYLAND.												
Cheltenham	38 44 00	76 50 30	71.6	Two Bosch-Omori 10 and 12-kg.	10	14	......	10	14	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	George Hartnell.
MASSACHUSETTS.												
Cambridge	42 22 36	71 06 59	5.4	Two Bosch-Omori 100-kg., horizontal pendulum, mechanical registration.	80	23	0	50	25	4:1	Harvard University seismographic station.	J. B. Woodworth.
MISSOURI.												
St Louis	38 38 15	90 13 58	160.4	Wiechert 80-kg., astatic, horizontal pendulum.	80	7	5:1	......		......	St. Louis University, geophysical observatory.	J. B. Goesse, S. J.
NEW YORK.												
Buffalo	42 53 02	78 52 40	180.5	Wiechert 80-kg., horizontal.	80	7	5:1				Canisius College	John A. Curtin, S. J.
Ithaca	42 26 58	76 29 09	242.6	Two Bosch-Omori 25-kg., horizontal pendulum, mechanical registration.	13	22	4:1	14	25	4:1	Cornell University	Heinrich Ries.
New York	40 51 47	73 53 08	23.9	Wiechert 80-kg.	72	5.0	0	72	5.0	0	Fordham University	D. H. Sullivan, S. J.
PANAMA CANAL ZONE.												
Balboa Heights	8 57 39	79 33 29	27.6	Two Bosch-Omori 100-kg. and 25-kg.	35	20	......	10	20	......	Panama Canal, Department Operation and Maintenance.	Governor, Panama Canal.
PORTO RICO.												
Vieques	18 09 00	65 27 00	19.8	Two Bosch-Omori	10	17	......	10	19	......	U. S. Coast and Geodetic Survey, Magnetic Observatory.	W. M. Hill.
VERMONT.												
Northfield	44 10 00	72 41 00	256	Two Bosch-Omori mechanical registration.	10	15	......	10	16	......	U. S. Weather Bureau	Wm. A. Shaw.
CANADA.												
Ottawa	45 23 38	75 42 57	83	Two Bosch photographic horizontal pendulum, one Spindler & Hoyer 80-kg. vertical seismograph.	120	26	......			......	Dominion Observatory, earthquake station.	Otto Klotz.
Toronto	43 40 01	79 23 54	113.7	Milne horizontal pendulum, North, in the meridian.	......	18	......			......	Dominion Meteorological Service.	
Victoria	48 24 00	123 19 00	67.7	Wiechert, vertical; Milne horizontal pendulum, North, in meridian.	......	18	......			......	....do	

[1] Sensitivity.

For the reports of the stations at the University of California, Berkeley, Calif., and at the Lick Observatory, Mount Hamilton, Calif., see *Bulletin of the Seismographic Stations, University of California;* for the report of the station at the University of Santa Clara, Santa Clara, Calif., see *Record of the Seismographic Station, University of Santa Clara.*

TABLE 1.—*Noninstrumental earthquake reports, January, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity, Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1920.	H. m.		° ′	° ′			Sec.			
Jan. 1	2 20	Corona	33 52	117 35	4	1	Short.	None	Doors rattled	T. C. Sias.
	2 25	Escondido	33 06	117 05	5	1	5	...do	Felt by many	H. L. Harlow.
		Warner Springs	33 15	116 45	5	1		...do	Cracked adobe walls	J. A. Ream.
	2 30	Nellie	33 22	116 52	5	1	60	Faint rumbling	Rapid trembling shock	J. P. Rolarts.
	2 34	Calexico	32 41	115 30	3	1	5	...do		H. M. Rouse.
		Elsinore	33 37	117 15	5	1		None	Felt by many	W. L. Wilhite.
		Hemet	33 45	116 58	5	2	4	Rumbling	...do	C. S. McManigal.
	2 35	San Diego	32 40	117 10	4	1	1	None	Chandeliers moved	U. S. Weather Bureau.
	2 37	El Cajon	32 48	116 58	4	1		Rumbling	Felt by several	E. P. Kessler.
	2 40	Julian	33 05	116 37	5	2	6	Loud rumbling	Felt by many	J. H. L. Vogt.
		Mesa Grande	33 11	116 42	5	2	13	Muffled	Jarring motion	E. H. Davis.
		Mount Wilson	34 13	118 16	2	1	12	Faint	Star images in 60-inch telescope vibrated rapidly.	Mount Wilson Observatory.
	2 46	Aguanga	33 26	116 51	5	1	2	Loud	Abrupt bumping motion	A. J. Berg.
30	23 30	Santa Barbara	34 23	119 40	3	1	2	None	Felt by several	A. W. Mutter.
	23 33	...do			2	1	2	...do	...do	Do.
	23 35	...do			2	1	2	...do	Felt by one	Do.
	23 38	...do			2	1	2	...do	...do	Do.
31	1 00	...do			3	1	2	...do	...do	Do.
	1 03	...do			3	1	2	...do	...do	Do.
	1 07	...do			3	1	2	...do	...do	Do.
		WASHINGTON.								
24	7 09	Clallam Bay	48 15	124 15	5	3	10-15	Rumbling	Most severe ever noticed	M. Rasmussen.
	7 10	Blaine	49 00	122 45	4	1	8	...do	Felt by many	J. Crilly.
	7 12	Marietta	48 47	122 35		2	5	...do	...do	S. B. Mayhew.
	7 14	Anacortes	48 50	122 40	5	2		Loud rumbling	Long duration	D. Allmond.
	7 15	Tatoosh	48 23	124 45	2	3	Few.	None	Felt by one	Mrs. A. K. Willis.
	7 20	Forks	47 56	124 20	5	2	60	Faint rumbling	Many awakened	Mrs. Ruth Johnson.

TABLE 2.—*Instrumental seismological reports, January, 1920.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and descriptions of instruments and stations, see this REVIEW, p. 62.]

ALABAMA. *Spring Hill College, Mobile.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 4		eP	4 26 48				1,410?	*Southern Mexico;* record peculiar—periods all short; P and S have same period; interval S-P too short; L absent. E damped, N undamped, yet records identical. Seems to be a superimposition of P waves of different shocks.
		iS or P	4 29 14	3.5				
		M	4 29 18	3.5	*5,300	*5,300		
		F	4 43 00					

* Trace amplitude.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 1		eP_E	2 35 41					
		P_N	2 36 12					
		L_E	2 36 22					
		M_E	2 37 11		50			
		M_N	2 36 46			20		
		F_E	2 41 00					
		F_N	2 40 00					
4		P_E	4 25 33	4				Time marks missing for 12 minutes before L on N; times of P and S interpolated over that interval.
		P_N	4 25 44					
		S_E	4 29 03					
		S_N	4 29 14					
		L_E	4 31 00	16				
		L_N	4 31 00					
		M_E	4 33 15		720			
		M_N	4 33 05	9		400		
		C_E	4 39 00	9				
		C_N	4 37 00	8				
		F_E	5 00 00	6				
		F_N	4 43 00					
12		e_N	23 04 38					Irregular record; possibly not seismic. Time marks missing.
		M_N	23 10 35			50		
		F_N	23 18 00					
25		e_N	0 13 35					Do.
		F_N	0 28 00					
25		e_N	20 25 01			20		Do.
		M_N	20 37 55					
		F_N	20 42 00					

TABLE 2.—*Instrumental seismological reports, January, 1920*—Contd.

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 1			2 42 00		500	700		Intensity, 2-3; Rossi-Forel.
14					100	100		Tremors during the hours preceding 15 h.

COLORADO. *Sacred Heart College, Denver.*

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 4		P	4 26 00					P rather indistinct.
		S	4 30 00					
		L_N	4 35 00	8		*2,000		
		L_E	4 35 00	8	*2,500			
		M_N	4 35 00	8		*3,000		
		M_E	4 36 30	6	*6,000			
		C_N	4 40 00					
		C_E	4 38 00					
		F_N	4 46 00					
		F_E	4 44 00					
15		L	13 30 00					Distinct but too small to be analyzed.
		F	13 40 00					
17								Activity visible at intervals during day.
20		L_N	13 46 00					Distinct but very small.
		F_N	13 59 00					
22								Wavelets at intervals during day.
25								Thickening of penmarks and wavelets during day.

* Trace amplitude.

WASHINGTON, D. C. *Georgetown University.*

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 4		eP_E	4 27 53					
		eP_N	4 27 53					
		S_E	4 32 52					
		S_N	4 32 46					
		eL	4 35 18					No distinct *M*.
		F	5 20 00					
30		eP_E	18 33 18					Heavy micros.
		eP_N	18 33 18					
		S	18 39 11					
		eL_E	18 43 18	10				No distinct *M*.
		L_E	18 44 48	16				
		L_N	18 46 22	18				
		F	19 *ca.*					

TABLE 2.—*Instrumental seismological reports, January, 1920*—Con.

WASHINGTON, D. C. *U. S. Weather Bureau.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 4		P	4 28 00					Time correction uncertain.
		S	4 32 40					
		P?	4 34 00					
		S?	4 39 05					
		eL	4 40 00					L nowhere well defined.
		F	5 15 *ca.*					Lost in micros. Whole record jumbled; apparently two quakes superimposed.
26		eL	21 37 30					
		F	21 45 *ca.*					
26		P	23 06 40					Time correction not certain.
		S?	23 10 35					
		F	23 15 *ca.*					
30		eP	18 33 45					
		P_R1	18 39 15					
		S	18 41 50					
		L	18 44 45					
		F	19 10 *ca.*					

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 1		P	12 21 42					
		eL	12 34 30					
		M	12 46 42	15	*200			
		C	12 52 42					
		F	13 36 42					
1		eP	15 47 00					
		L	16 01 30					
		M	16 09 30	18	*100			
		C	16 15 00					
		F	16 22 00					
2		e	13 33 24					
		M	13 37 12	15	*100			
		C	13 40 00					
		F	13 45 00					
4		S	4 39 36	15				First recorded motion?
		S_R1	4 45 48	20				
		L	4 50 00					
		M	4 54 30	18	*1200			
		C	4 57 00					
		F	5 32 00					
7		eP	9 33 00					Beginning and end obscured by continuous slight tremors, probably microseismic.
		L	9 43 00					
		M	9 47 00	15	*300			
		C	9 50 00					
12		P_R1	13 57 42					Air tremors present throughout.
		S	14 02 24	18				
		L	14 06 36					
		M	14 17 42	16	*2100			
		C	14 26 00					
		F	14 50 00					
13		eP	23 10 12	16				
		L	23 23 36					
		M	23 34 36	19	*1400			
		C	23 43 00	17				
		F	24 19 00	16				
14		eP	14 49 00	15				Phases ill-defined.
		S	14 56 24	20				
		L	15 05 54					
		M	15 16 06	17	*300			
		C	15 34 00	20				
		F	16 02 00	20				
21		P	6 18 30	19				
		L	6 21 00					
		M	6 21 42	15	*200			
		C	6 28 00	20				
		F	6 44 00	18				
22		iP	21 35 24	20				
		S	21 40 24	18				
		eL	21 43 42					
		M	21 46 30	20	*400			
		C	21 54 00	15				
		F	22 40 00	19				
26		eP	11 35 48	20				
		eL	11 52 00					
		M	11 55 06	17	*200			
		C	11 57 00	18				
		F	12 18 00	20				
30		eP	19 47 12	16				
		S	19 50 00	15				
		eL	19 52 42					
		M	19 57 30	19	*800			
		C	20 00 00	20				
		F	20 47 00	18				

* Trace amplitude.

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TABLE 2.—*Instrumental seismological reports, January, 1920*—Con.

ILLINOIS. *U. S. Weather Bureau, Chicago.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 1		L	12 59 *ca.*	22				
		L	13 08 00	16				
		F	13 40 00					Lost in micros.
1		L	16 29 00	20				Very heavy micros; may not be seismic.
		F	16 40 *ca.*					
4		P	4 27 26				2,670	
		S	4 31 44					From beginning of S. record very confused.
		L_E	4 33 52					
		F	5 50 *ca.*					
13		L	23 56 00	24				
14		L	0 05 00	18				
		F	0 30 *ca.*					Lost in very heavy micros.
14		eL	15 37 30					
		L	15 37 35	18				Lost in heavy micros.
		F	16 10 00					
22		eL	22 11 00					
		L	22 15 00	22				
		L	22 18 00	18				
		F	23 *ca.*					Lost in micros.
26		e	21 31 00					Phases indeterminable.
		F	22 10 *ca.*					Do.
26		P_E	23 12 00					
		F	23 30 *ca.*					
30		P	18 34 50					
		PR_1	18 39 50					
		S	18 42 35					
		L	18 47 00					
		L	18 57 00	15				
		F	20 *ca.*					Lost in micros.

KANSAS. *University of Kansas, Lawrence.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 4		eP_E	4 26 48		*500		2,020	
		eS_E	4 30 13					
		L_E	4 33 12					
		M_E	4 38 00		*2,500			
		F_E	4 59 15					

* Trace amplitude.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 4		P_E	4 27 37	4				
		P_N	4 27 44	4				
		S_E	4 32 36	3–8				
		S_N	4 32 23	2–8				
		eL_N	4 38 47					L waves not definitely shown on E.
		M_E	4 32 50		10			
		M_N	4 42 30	12		40		
		F_E	5 01 00					
		F_N	5 05 00					

MISSOURI. *St. Louis University, St. Louis.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Jan. 4		P	4 26.85				2,330	L not distinguishable.
		S	4 30.65					
		M	4 37.50					
		F	4 58 00					

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1920.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Jan. 4		eP_E	4 28 32					No definite phases.
		eP_N	4 28 45					
		eL_E	4 36 50		10			
		F	4 50 00					
15		P_E	16 26 30					Small waves of period from 1½ to 3 seconds overlie the longer waves for most of the record.
		P_N	16 26 30	2				
		L_E	16 26 51					
		L_N	16 26 56					
		M_E	16 27 33	9	80			
		M_N	16 27 21			100		
		C_E	16 28 00					
		C_N	16 30 00	5				
		F	16 38 00	5				
26		P	21 23 51	1				Felt strongly in Porto Rico. On N there is a faint disturbance beginning 21:23:27, which may be P of an earlier shock.
		L	21 24 22					
		M_E	21 24 54	9	60			
		M_N	21 24 47	13		140		
		C_E	21 27 00	6				
		C_N	21 26 00	6				
		F_E	21 43 00					
		F_N	21 34 00	6				

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, January, 1920*—Con.

PORTO RICO.—*U. S. C. & G. S. Magnetic Observatory, Vieques*—Con.

1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 26		P	23 02 37	2				Felt strongly in Porto Rico.
		L	23 03 01					
		M_E	23 03 29	9	90			
		M_N	23 03 24	10		260		
		F	23 12 00	4				
30		P_E	18 31 33	7				P distinct on both components; other phases indefinite.
		P_N	18 31 32	6				
		eS_E	18 35 24					
		eL_E	18 39 30					
		M_E	18 39 45		20			
		F_E	18 51 00					
		F_N	18 38 00					

VERMONT. *U. S. Weather Bureau, Northfield.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan 4		eL	4 45 00					Amplitude very small.
		F	5 05 00					

CANADA. *Dominion Observatory, Ottawa.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 4		*O*	4 22 03				3,440	
		eP	4 28 39					
		eS	4 33 52					S waves seem to have short period P waves of a second shock superimposed upon them.
		eL?	4 37 42					
		L	4 45 00	15				
		L	4 55 00	8				
		F	5 15 00					
14			0 00 00					Traces of disturbances; phases lost in very heavy micros; may not have been seismic.
			14 49 00					
30		*O*	18 28 07				3,820	
		eP	18 35 12					
		$eP_E?_N$	18 36 08					
		S	18 40 49					
		L	18 44 20	24				
		L	18 48 00					
		F	19 10 00					
30		L_E	20 30 to 20 40 00	20				

CANADA. *Dominion Meteorological Service, Toronto.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 1								Small micros masked sheet at 2h. 42m. when other station records quake.
1		L	13 01 48					Micros masked initial phases.
		eL	13 06 24					
		M	13 10 30		*300			
		L	13 13 30					
		F						Lost in micros.
1		eL	16 37 18					Gradual thickening, well marked.
		M	16 40 36		*200			
		F						Lost in micros.
2								Small micros masked sheet at 13h. 20m. when other station records quake.
4		P	4 27 36				3,600	Disastrous Mexican quake.
		P	4 28 48					
		S	4 33 00					
		L	4 41 54					
		L	4 43 24					
		eL	4 44 48					
		M	4 47 48		*1,000			
		eL	4 51 18					
		F	5 23 36					
7								Irregular instrumental clockwork prevented record of quake recorded at other station at 9h. 44m.
12		L	14 16 42					
		L	14 22 42		*100			
12		L	14 30 06					May not be seismic.
		eL	14 44 12					
		M	14 46 30		*200			

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, January, 1920*—Con.

CANADA.—*Doninion Meteorological Service, Toronto*—Continued.

1920.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 13		P?	23 27 30					
		L	23 54 00					
14		L	0 00 06					
		L	0 04 18					
		eL	0 06 12					
		M	0 13 30		*300			
		eL	0 20 36					
		F?	0 54 30					
14		L	1 02 06					May not be seismic.
		eL	1 18 36					
		M	1 19 48		*200			
		F?	1 22 36					
14		P	15 41 48					
		L	15 49 12					
		eL	15 50 30					
		M	15 54 42		*800			
		F	16 51 36					
14		L	17 33 18		*100			
15		L	12 37 36					
		L	12 47 54					Last two phases may not be seismic.
		M	12 49 42		*200			
20		L	17 00 24					May not be seismic.
		M	17 01 48		*200			
		F	17 17 36					
22		eL	22 25 06					
		M	22 30 12		*300			Gradual thickening.
		F	22 45 00					
22		eL	23 58 18					
		M	23 59 18		*200			
23		F	0 06 24					
24		L	7 17 54		*100			May not be seismic.
		L	7 37 54					
30		P?	18 37 00					Small micros render P. entry doubtful.
		eS	18 43 18					
		iL	18 47 30					
		M	18 49 54		*1,300			
		F						
30		L	20 29 18					
		L	20 32 12		*200			Micros going on.
		F						

* Trace amplitude.

CANADA. *Dominion Meteorological Service. Victoria.*

1920.			H. m. s.	Sec.	μ.	μ.	Km.	
Jan. 1		P	2 42 06					
		M	2 46 02		*100			
		F	2 49 58					
1		L	12 46 04					
		M	12 50 59		*100			
		F	13 21 29					
2		P	13 20 35				665	May be off west coast.
		L	13 22 04					
		M	13 22 33		*500			
		F	13 30 25					
				VERTICAL.				
		P	*13 20 10*	*2*			520	
		S. & L	*13 21 20*	*7*				
		M	*13 23 00*	*8*	*4*			
4		P	4?30 29				2,390?	Destructive Mexican quake.
		S	4 34 25					
		L	4 40 49					
		iL	4 45 38					
		M	4 47 42		*1,600			
		F	5 33 55					
				VERTICAL.				
		P	*4 29 25*	*2*			3,170	
		S	*4 34 20*	*6*				
		L	*4 43 30*	*12*				
		M	*4 47 46*	*10*	*4*			
7		M	9 44 56		*200			
		F	9 50 53					
12		P	14 00 50				3,620	Mexico?
		S	14 05 15					
		L	14 12 38					
		M	14 18 32		*400			
		F	14 53 56					
13		P	23 23 32					
		L	23 40 15					
		M	23 45 45		*700			
		F	1 45 10					

* Trace amplitude.

Table 2.—*Instrumental seismological report, January, 1920*—Con.

Canada. *Dominion Meteorological Service. Victoria*—Continued.

1920.			h m s					
Jan. 14	....	P.....	15 02 25	....	....	....	4,120	Mexico?
		S.....	15 08 19	....	....	....	....	
		L.....	15 19 08	....	....	....	....	
		M.....	15 27 29	....	*400	....	....	
		F.....	17 03 53	....	....	....	....	
15	....	L.....	12 28 04	....	....	....	....	
		M.....	12 32 29	....	*100	....	....	
		F.....	12 39 52	....	....	....	....	
21	....	M.....	6 30 47	....	*50	....	....	
		F.....	6 42 41	....	....	....	....	
22	....	P.....	21 42 00	....	....	....	....	
		S.....	21 48 06	....	....	....	4,330	Probably Mexico?
		L.....	21 55 46	....	....	....	....	
		M.....	22 03 22	....	*500	....	....	
		F.....	22 43 29	....	....	....	....	
24	....	P.....	7 09 16	....	....	....	35	Probably under Strait of Georgia and northeast of Victoria.
		M.....	7 09 20	....	*2,000	....	....	
		F.....	7 24 01	....	....	....	....	
				Vertical.				
		P.....	*7 09 16*	*1*	....	....	35	
		L.....	*7 09 18*	*2*	....	....	....	
		M.....	*7 09 20*	*3*	*214*	....	....	
		F.....	*7?12 30*	....	....	....	....	
30	....	P.....	18 44 23	....	....	....	3,620?	
		S.....	18 49 48	....	....	....	....	
		L.....	18 54 42	....	....	....	....	
		M.....	19 12 30	....	*500	....	....	
		F.....	19 24 00	....	....	....	....	
30	....	M.....	20 13 01	....	*400	....	....	
		F.....	20 24 25	....	...	....	....	

* Trace amplitude.

The following stations recorded no earthquakes during January, 1920:

Alaska. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Reports for January, 1920, have not been received from the following stations:

Massachusetts. Harvard University, Cambridge.
New York. Canisius College, Buffalo; Cornell University, Ithaca; Fordham University, New York.
Canal Zone. Department of Operation and Maintenance, Panama Canal.

SEISMOLOGICAL DISPATCHES.[1]

Mexico City, Mexico, January 3.—One of the earth shocks that are not uncommon here was felt at 10 o'clock to-night. The shock was more severe than that of December 17, but did not cause as much apprehension as the December seismic disturbance, which came on the date of a groundless prediction of a cataclysm from astronomical causes. Incomplete press reports indicate that the State of Vera Cruz suffered more than any other section, although seismic disturbances were felt throughout the entire Republic. Advices from Cordoba say that 30 dead have already been accounted for in the village of San Juan Coscomatepec, where many houses were destroyed. There are unconfirmed reports of a similar catastrophe in the village of Huatusco. At Jalapa, farther north, 50 victims of the earthquake have been counted, including numerous dead. Lack of communication with the other small towns and villages in the theater of disturbance makes even approximate estimates of the casualties impossible. The earthquake caused great alarm in the large cities. Marine disturbances have occurred off Vera Cruz city, and there were some casualties there, although the number is not known, with considerable destruction of property. Late reports received here say that the death list in San Juan Coscomatepec was augmented as a result of the collapse of the church tower, which crashed in upon the crowds gathered inside the edifice to pray, following the first shock. Vera Cruz city is without water, while the lighting systems of Orizaba and Jalapa are out of commission. The villages of Teocelo and Couztlan, in the State of Vera Cruz, were virtually destroyed by the earthquake last night, and heavy casualties have resulted, according to late press reports received here.—(A)

Mexico City, Mexico, January 5.—Reports received up to 11 o'clock last night indicated the center of the seismic convulsion was in the neighborhood of Mount Orizaba, a volcano situated about 70 miles west of Vera Cruz on the line between the States of Vera Cruz and Pueblo. It was in this neighborhood that the most serious damage was done. Teocelo, a village 35 miles northeast of the volcano, has been virtually destroyed, and a similar fate befell Couztlan, a small hamlet in that neighborhood. Wires have been torn down by the violence of the tremor, and only fragmentary reports have reached this city, but it is stated that there were many casualties in both towns. Many houses and churches in Jalapa, a city 50 miles northwest of Vera Cruz, were damaged, while reports from Orizaba, a city 10 miles south of the volcano, state that several business blocks and churches near the center of the town were cracked. In the suburbs of Orizaba the shock was very severe, many persons being reported killed beneath their wrecked houses. Fifteen shocks were experienced at Cordoba, a city 10 miles east of Orizaba, where 11 were distinctly felt. First reports received here stated that the tremor centered at Acambaro, a town near Teluca, about 25 miles southwest of Mexico City, but more recent advices state the shocks were not severe there.—(A)

Mexico City, Mexico, January 8.—A violent volcanic eruption has been caused by the recent earthquake near Cordoba, where Cero de San Miguel, a small and apparently extinct volcano, has been burst in twain. The new crater is throwing out smoke, ashes, and flame, while lava is flooding the near-by territory in a stream more than 200 yards wide, resulting in not less than 200 deaths.—(A)

Mexico City, Mexico, January 13.—San Joaquin, a village of 3,000 inhabitants in the Jalapa district, State of Vera Cruz, was destroyed this morning by an earthquake, according to advices given out by the department of agriculture, which gave no details as to casualties. Shocks were detected at the astronomical observatory near this city at 5:18 o'clock this morning.—(A)

Mexico City, Mexico, January 22.—Strong earthquake shocks were felt in the city of Vera Cruz from 3 to 5 o'clock this morning. There were no casualties, although some residences were damaged. Reports from Vera Cruz state the tremors demolished at Couztlan all structures which were not destroyed in the earthquake of January 6, while shocks lasting 20 minutes caused further damage at Salmoral and San Francisco de las Penas.—(A)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C. [(A) indicates Associated Press.]

Paris, January 23.—Earth shocks along the coast of the Sea of Marmora are reported in a Havas dispatch from Constantinople under date of January 19.—(A)

Seattle, Wash., January 24.—Three distinct earthquake shocks were felt here at 11:08 o'clock last night. The tremors extended through Washington and British Columbia. At Bellingham, Wash., windows were broken and brick walls cracked. At Vancouver, B. C., people fled from buildings in alarm, but the only damage reported was to telephone lines. Victoria, B. C., and numerous towns in northwest Washington felt the quake. No damage was reported in Seattle.

Madrid, Spain, January 25.—The observatory at Toledo has issued a communique stating that at 5 o'clock Saturday afternoon (Jan. 24) the instruments at the observatory recorded a seismic disturbance at an estimated distance of approximately 275 miles.—(A)

Buenos Aires, Argentina, February 2.—Dispatches from the State of Minas Geraes, Brazil, report that an earthquake Sunday shook down a number of houses in the country districts, creating great panic among the inhabitants. The dispatches say that in intensity the earth shock is without precedent in that region.—(A)

LATE REPORTS (INSTRUMENTAL).

KANSAS. *University of Kansas, Lawrence.*

			H. m. s.	Sec.	μ	μ	Km.	
1919. June 29		eP_N	23 19 38			*500		
		eS_N?	23 24 23			*2,000		
		eL_N	23 29 00			*2,000		
		F?	23 59					
July 6		eP_N	7 09 24			*1,000		S and L not distinct.
		eP_E	7 09 25		*300			
		S_E?	7 11 41?					
		eL_N?	7 13 27			*1,500		
		L_E?	7 13 30		*2,000			
		F_N	7 30 17					
		F_E?	7 20 40					
9		eP_N	19 24 41				25 30	
		eP_E	19 24 42					
		eS_N	19 28 48					
		eS_E	19 28 54					
		L_N	19 31 57					
		L_E	19 31 59					
		M_N	19 32 15			*3,600		
		M_E	19 32 15		*1,900			
		F_N	19 56					
		F_E	20 00					
22		eP_N	22 03 09					Extremely minute record; phases obscure.
		eP_E	22 03 11					
		L_N?	22 07 42?			*500		
		L_E?	22 07 41?		*400			
		F_N	22 17?					
		F_E	22 18 50					
Sept. 15		eP_E	17 34 51					N-S component shows only L.
		eL_E	17 40 49					
		L_N?	17 41 03			*1,500		
		M_E	17 41 28		*4,000			
		F_E	17 47?					
		F_N	17 49					
Dec. 18		eP_E	1 25 02					No record by N-S component.
		eL_E	1 31 52		*900			
		F?	1 38 10					

* Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, January, 1920.

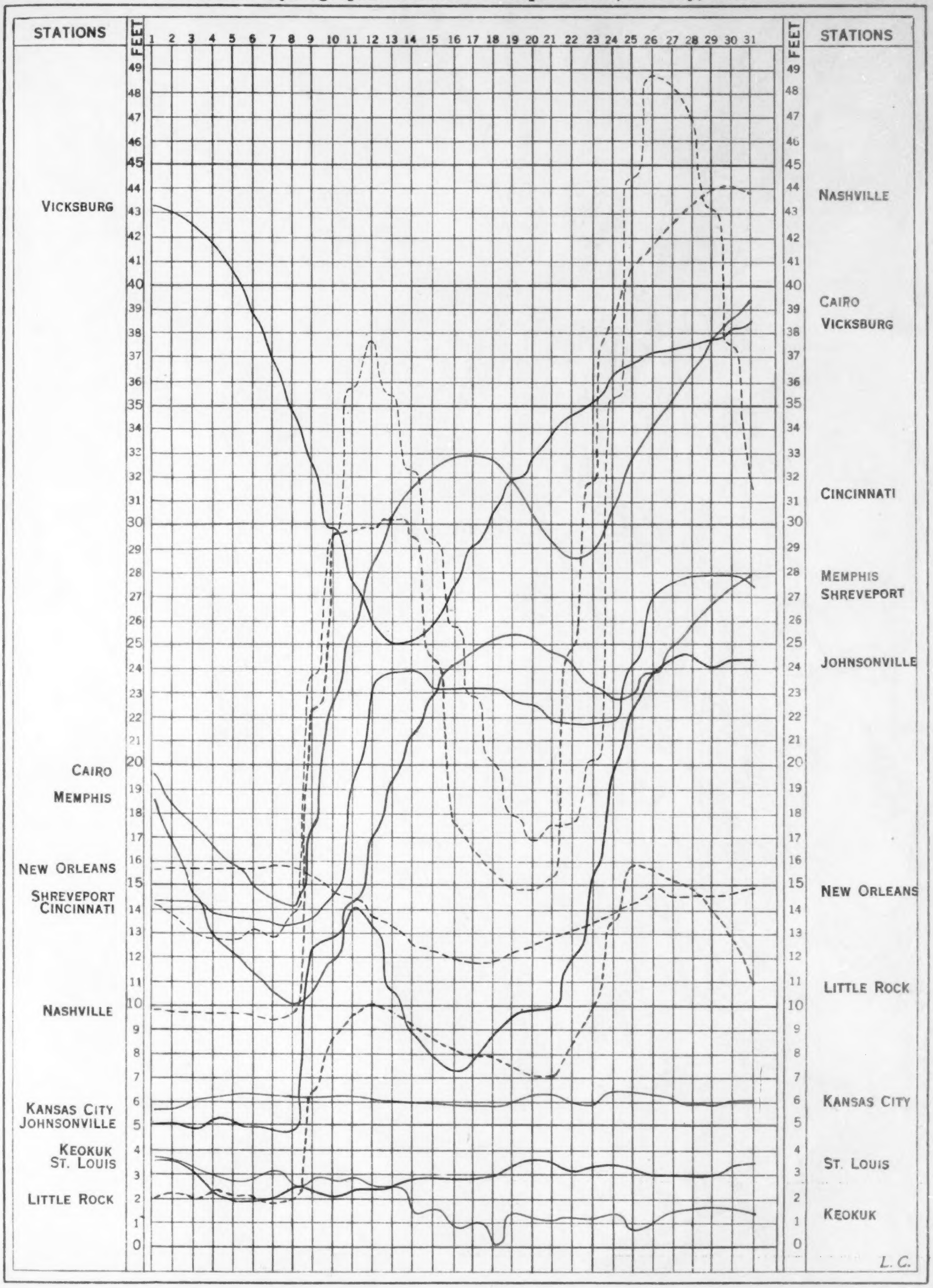


Chart II. Tracks of Centers of High Areas, January, 1920.

(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, January, 1920.

Chart III. Tracks of Centers of Low Areas, January, 1920.

(Plotted by R. H. Weightman, Meteorologist.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, January, 1920.

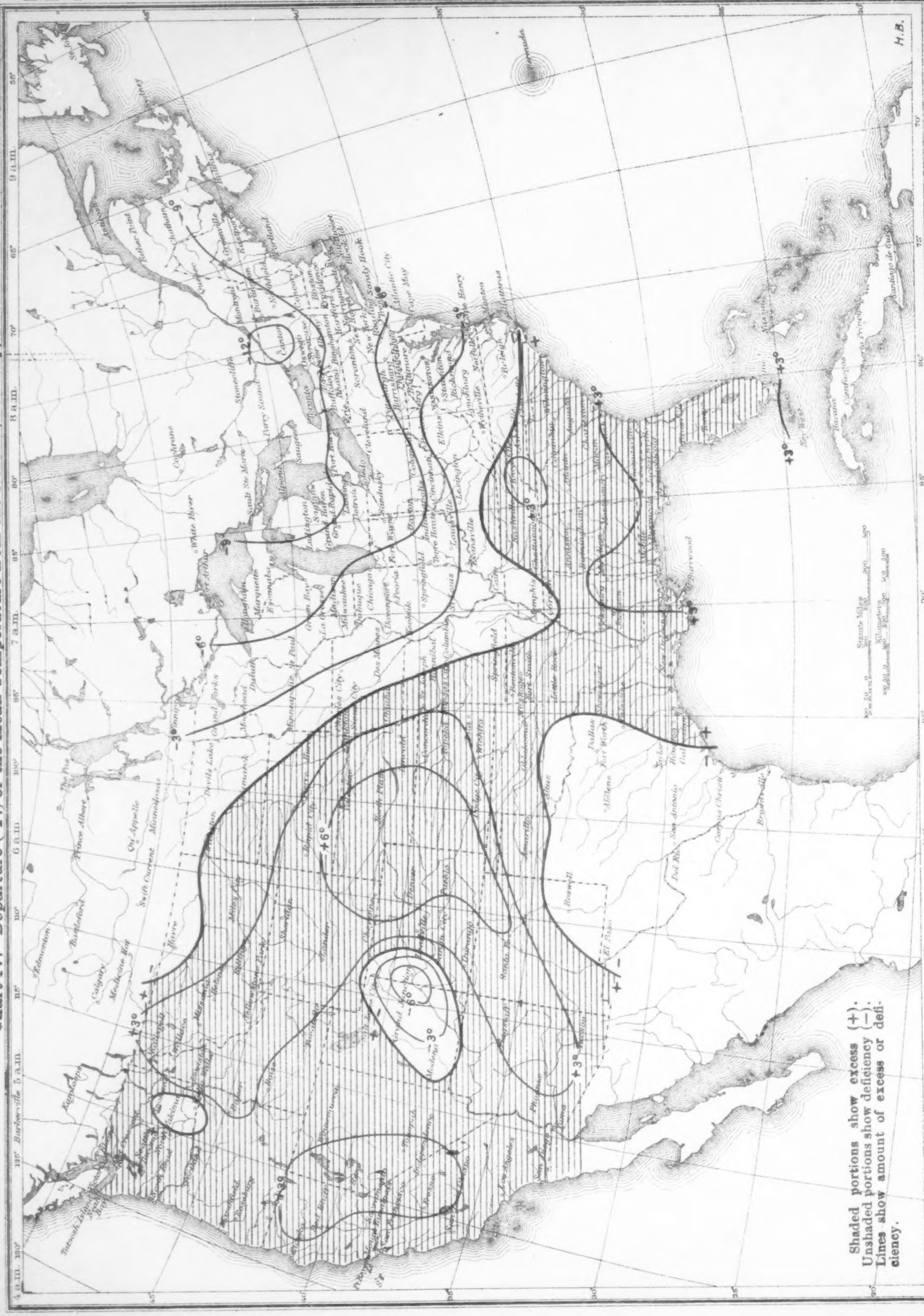
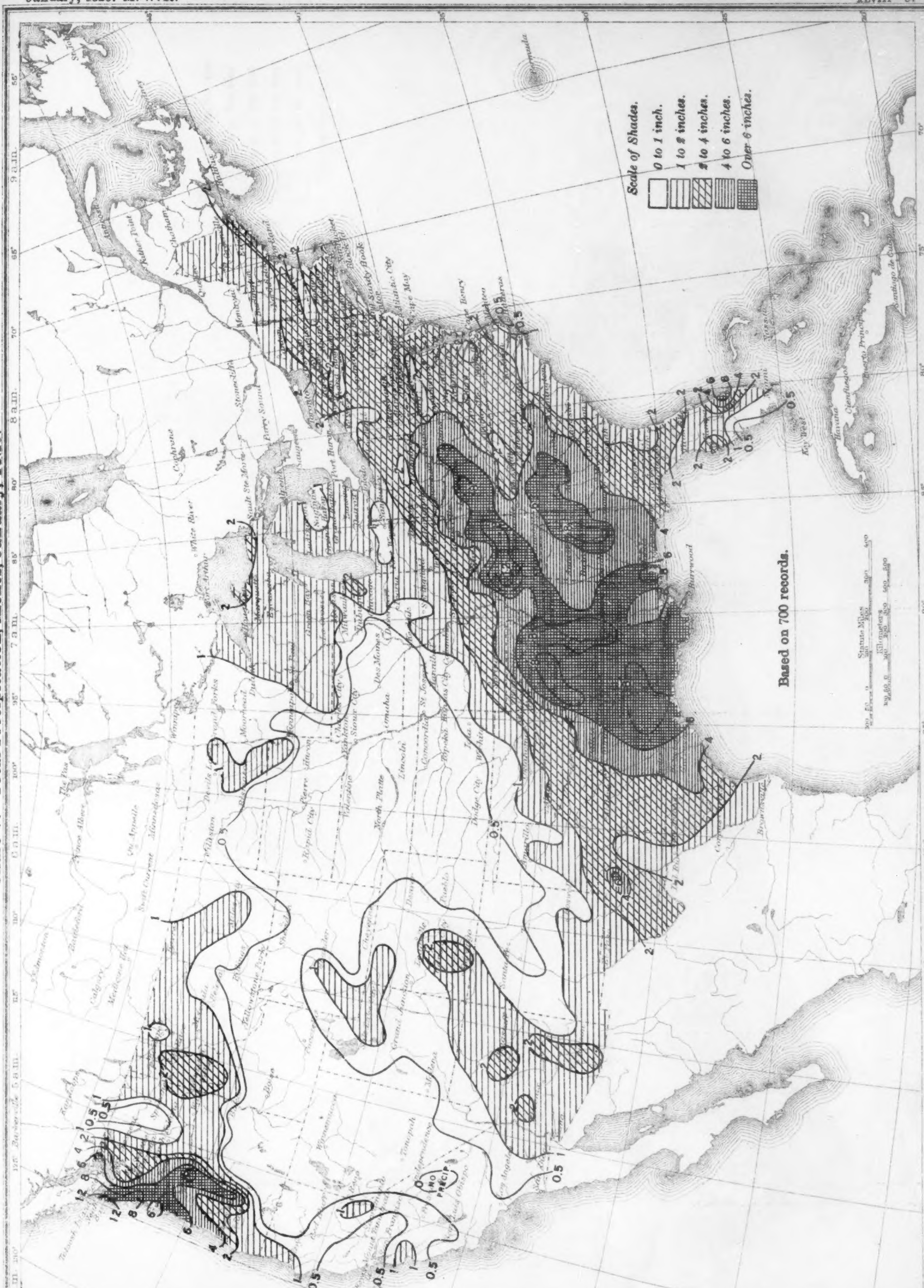


Chart V. Total Precipitation, Inches, January, 1920.



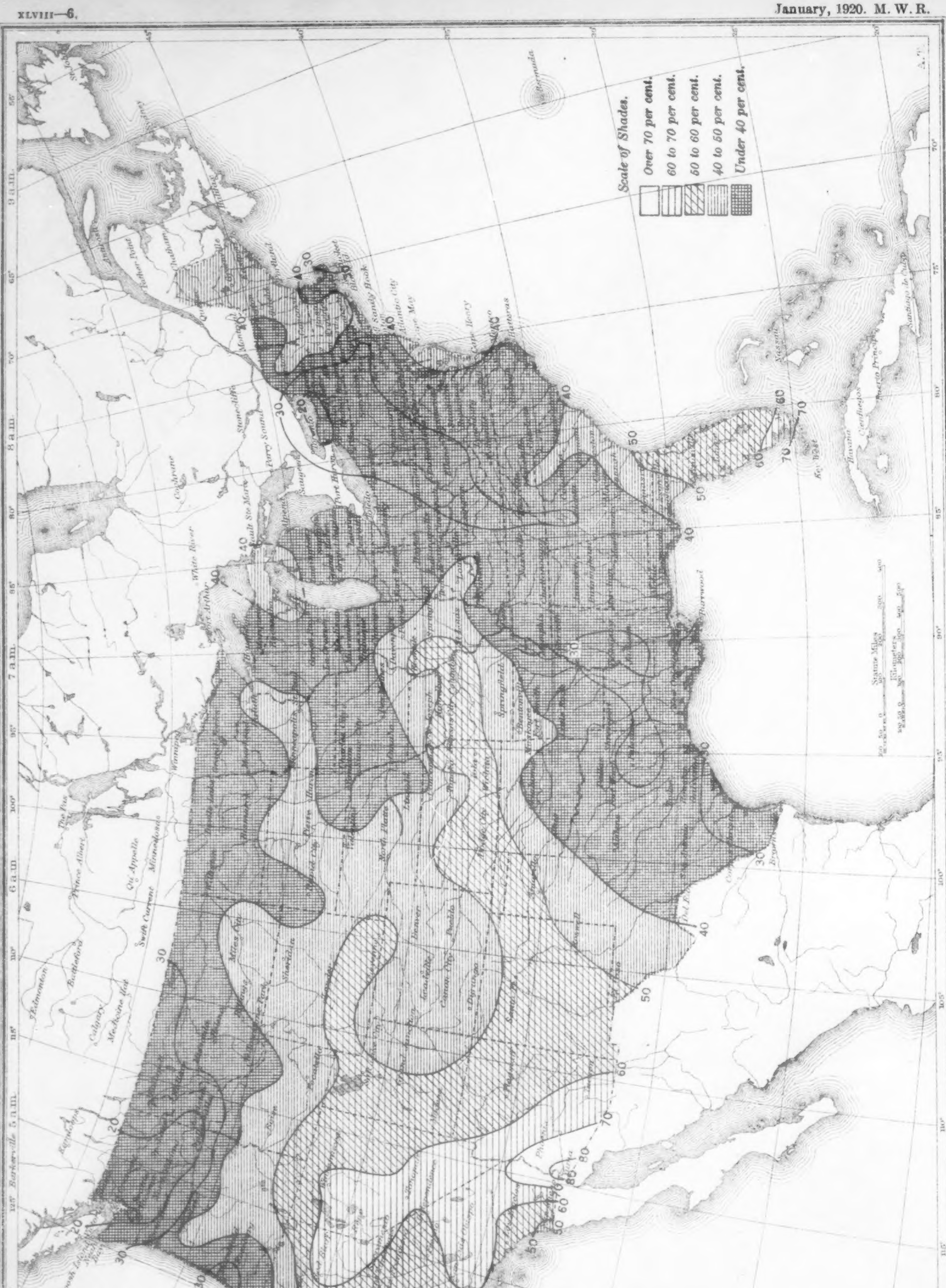


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, January, 1920.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, January, 1920.

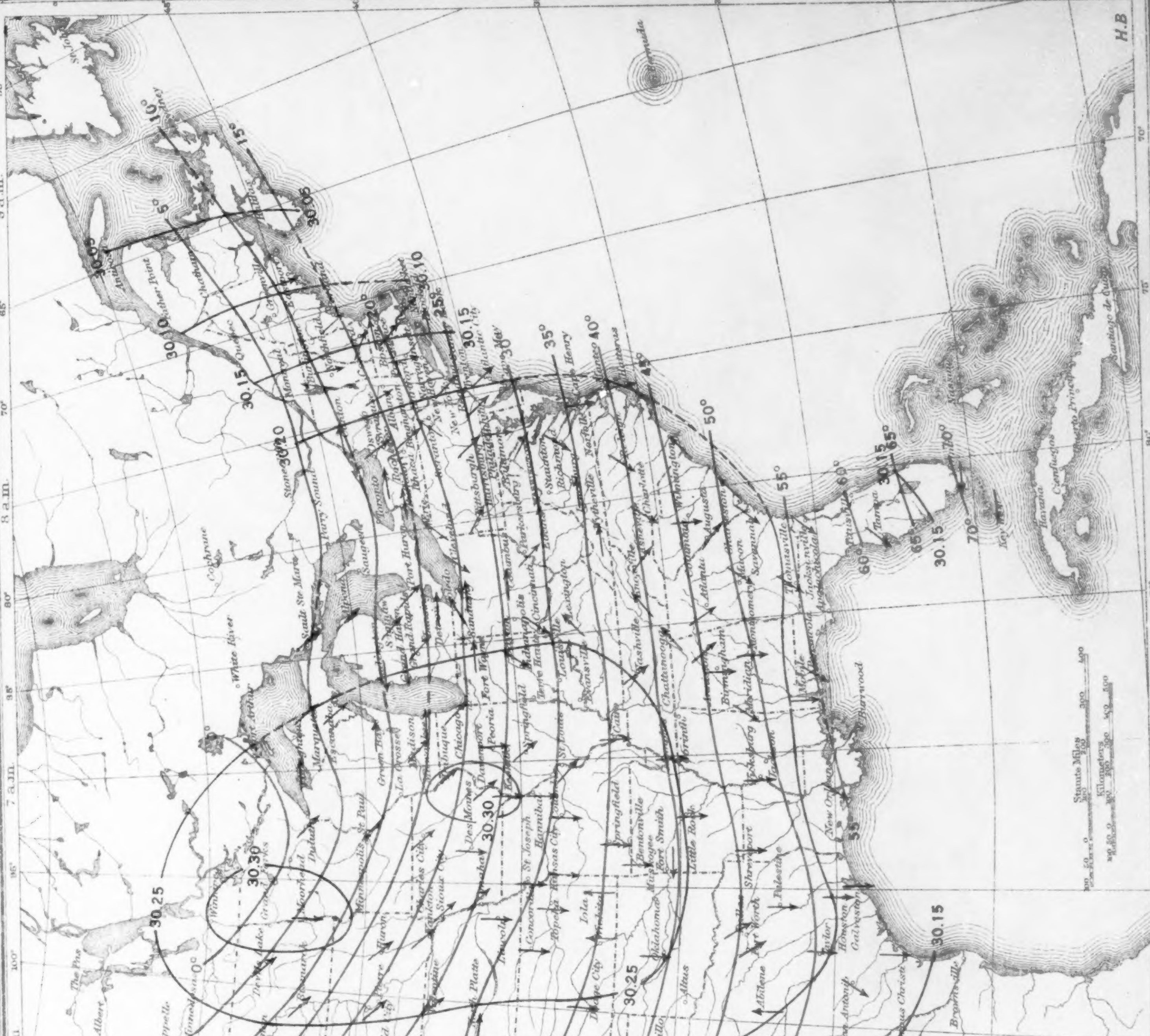


Chart VIII. Total Snowfall, Inches, January, 1920.

Chart IX. Weather Map of North Atlantic Ocean, January 1, 1920.

Chart IX. Weather Map of North Atlantic Ocean, January 1, 1920.

(Plotted by F. A. Young.)

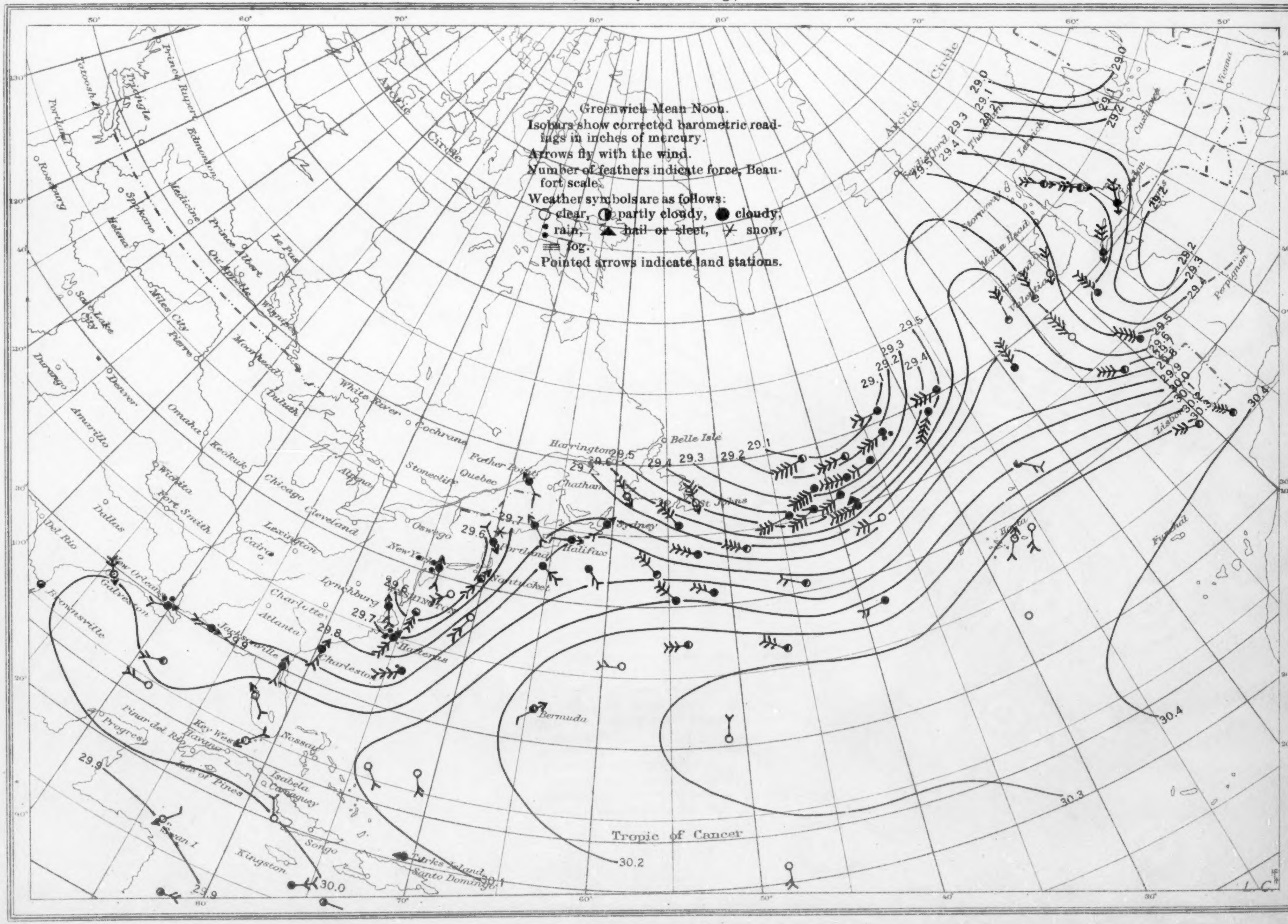


Chart X. Weather Map of North Atlantic Ocean, January 2, 1920.
(Plotted by F. A. Young.)

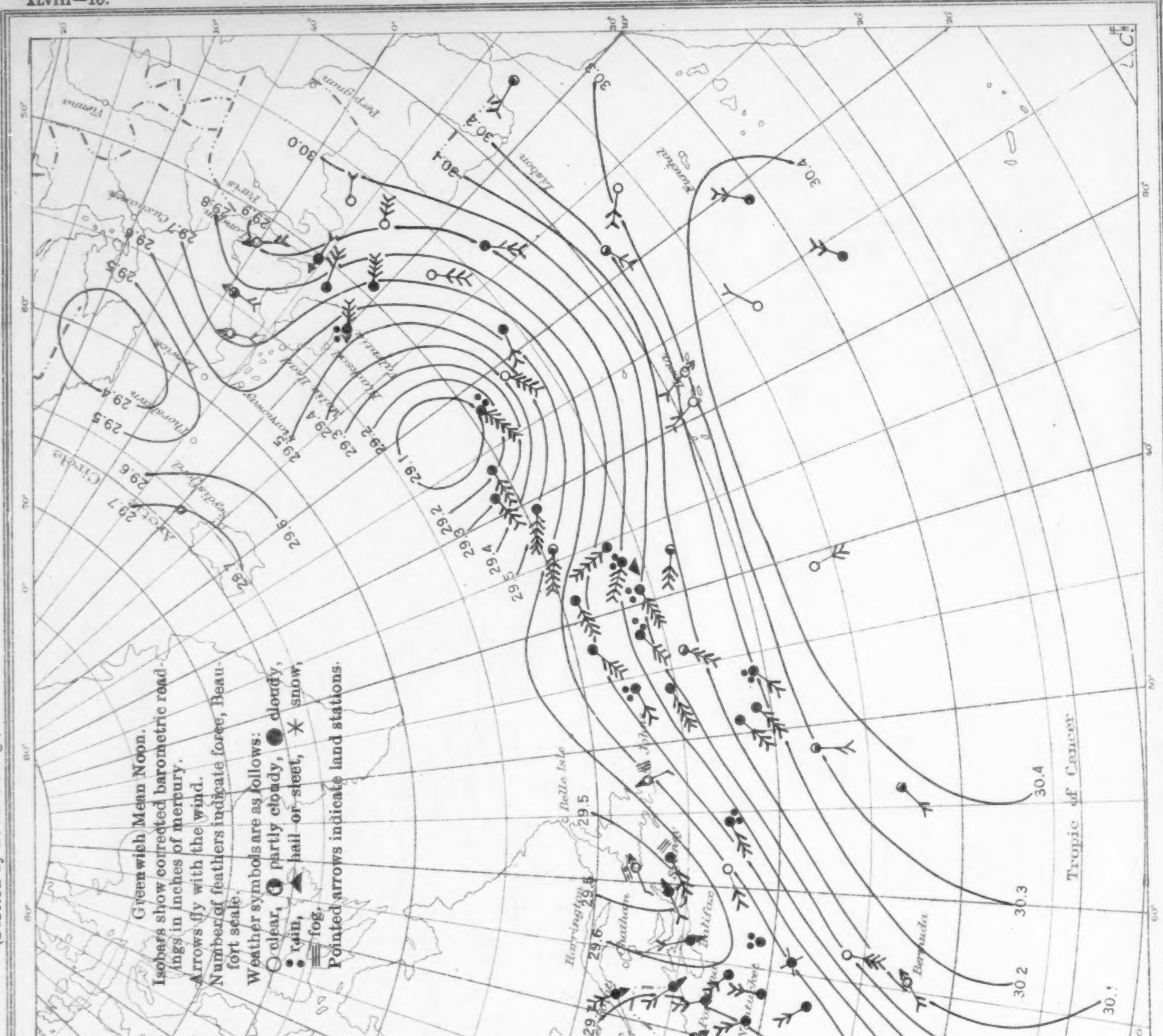


Chart XI. Weather Map of North Atlantic Ocean, January 13, 1920.

(Plotted by F. A. Young.)

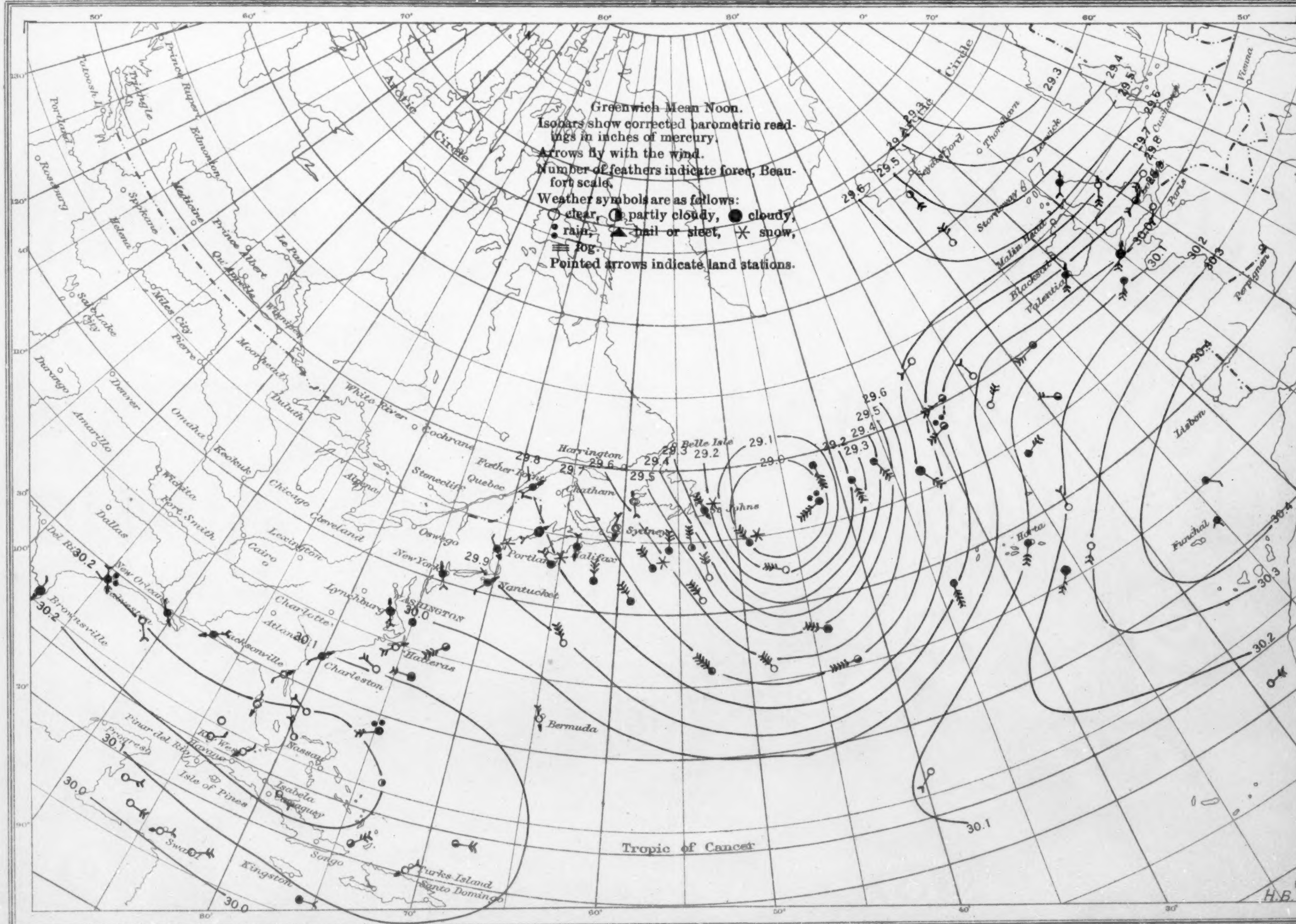


Chart XII. Weather Map of North Atlantic Ocean, January 14, 1920.
(Plotted by F. A. Young.)